ON

NARCOTISM

BY THE

INHALATION OF VAPOURS.

BY

JOHN SNOW, M.D.

THE FIRST SEVEN PARTS,

From the London Medical Gazette for 1848.

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Vapours when inhaled become absorbed. Method of determining the quantity in the blood in different degrees of narcotism. Experiments on animals for this purpose, with chloroform and with ether.

It is generally admitted that ether and chloroform, when inhaled, are imbibed and enter the blood; and this has been proved, as regards ether, in more ways than one. That substance has been detected in the blood of animals that have inhaled it; and I have proved its absorption as follows:—I passed a tame mouse through the quicksilver of a mercurial trough, into a graduated jar containing air and ether vapour, and, after a little time, withdrew it through the mercury, and introduced it, in the same manner, into a jar containing only air. On withdrawing it, and waiting till the air cooled to its former temperature, I found that the mercury had risen considerably in the first jar, and become depressed to some extent in the second; vapour of ether having been absorbed from one jar, and part of it exhaled into the other.

M. Lassaigne* endeavoured to ascertain the proportion of ether in the blood in etherization, by comparing the tension of the vapour of serum of the blood before and after inhalation, with that of an aqueous solution of ether in certain known proportions. This method would, no doubt, indicate the quantity of ether in the serum at the time it was examined; but part of the ether would escape from the blood, in the form of vapour, as soon as it came in contact with the air in its exit from the body. He made the quantity of ether in the blood to be 0·0008, or one part in 1250.

Dr. Buchanan*, by considering the quantity of ether expended in inhalation, and making allowance for what is expired, without being absorbed, considered the quantity in the blood of the adult in complete etherization to be not more than half a fluid ounce; and this is, I believe, a pretty correct estimate.

I consider, however, that I have found a plan of determining more exactly the proportion of ether and of other volatile substances present in the blood in the different degrees of narcotism. It consists in ascertaining the most diluted mixture of vapour and of air that will suffice to produce any particular amount of narcotism; and is founded on the following considerations, and corroborated by its agreeing with the comparative physiological strength of the various substances.

* Comptes Rendus, 8 Mars, 1847; and Med. Gaz. vol. xxxix. p. 968.

* Med. Gaz. vol. xxxix. p. 717.

When air containing vapour is brought in contact with a liquid, as water or serum of blood, absorption of the vapour takes place, and continues till an equilibrium is established; when the quantity of vapour in both the liquid and air, bears the same relative proportion to the quantity which would be required to saturate them at the temperature and pressure to which they are exposed. If, for instance, the liquid contains one per cent., and would require ten per cent. to saturate it, the air will contain three per cent. if thirty per cent. be the quantity that it could take up. This is only what would be expected to occur; but I have verified it by numerous experiments in graduated jars over mercury. The intervention of a thin animal membrane may alter the rapidity of absorption, but cannot cause more vapour to be transmitted than the liquid with which it is imbued can dissolve. The temperature of the air in the cells of the lungs and that of the blood circulating over their parietes is the same; and, therefore, when the vapour is too dilute to cause death, and is breathed till no increased effect is produced, the following formula will express the quantity of any substance absorbed:—As the proportion of vapour in the air breathed is to the proportion that the air, or the space occupied by it, would contain if saturated at the temperature of the blood, so is the proportion of vapour absorbed into the blood to the proportion the blood would dissolve.

The plan which I adopted to ascertain the smallest quantity of vapour, in proportion to the air, that would produce a given effect, was to weigh a small quantity of the volatile liquid in a little bottle, and introduce it into a large glass jar covered with a plate of glass; and having taken care that the resulting vapour was equally diffused through the air, to introduce an animal so small, that the jar would represent a capacious apartment for it, and wait for that period when the effects of the vapour no longer increased.

Experiments with Chloroform.

I will first treat of chloroform, and, passing over a number of tentative experiments, will adduce a few of those which were made after I had ascertained the requisite quantities. The effects produced in these experiments were entirely due to the degree of dilution of the vapour, for the quantity of chloroform employed was, in every instance, more than would have killed the animal in a much shorter time than the experiment lasted if it had been conducted in a smaller jar. It is assumed that the proportions of vapour and air remain unaltered during the experiment, for the quantity absorbed must be limited to what the animal can breathe in the time, which is so small a part of the whole that it may be disregarded.

Exp. 1.—A Guinea pig was placed in a jar, of the capacity of 1600 cubic inches, and the cover being moved a little to one side for a moment, 8 grs. of chloroform were dropped on a piece of blotting paper suspended within. The animal remained in the jar twenty minutes, and was not appreciably affected any part of the time.

Exp. 2.—The same Guinea pig was placed in the same jar, on another occasion, and 12 grs. of chloroform were introduced in the same manner, being three-quarters of a grain for each 100 cubic inches. In about six minutes it seemed drunk. It was allowed to remain for seventeen minutes, but did not become more affected; occasionally it appeared to be asleep, but could be disturbed by moving the jar. On being taken out it staggered, and could not find the way to its cage at first, but it recovered in two or three minutes.

Exp. 3.—Two grains of chloroform were put into a jar containing 200 cubic inches; it was allowed to evaporate, and the resulting vapour equally diffused by moving the jar; and then the cover was withdrawn just far enough to introduce a white mouse. After a short time it began to run round continuously in one direction. At the end of a minute it fell down and remained still, excepting a little movement of one or other of its feet now and then. It remained in the same state, and was taken out at the end of five minutes: it flinched on being pinched, tried to walk directly afterwards, and in a minute or so seemed to be completely recovered.

Exp. 4.—A Guinea pig was placed in the jar of 1600 cubic inches' capacity, and 20 grains of chloroform were introduced, as in the two first experiments, being a grain and a quarter for each

100 cubic inches. In two minutes the Guinea pig began to be altered in its manner. At the end of four minutes it was no longer able to stand or walk, but crawled now and then. After seven minutes had elapsed it no longer moved, but lay breathing as in sleep. It was taken out at the end of a quarter of an hour. It moved its limbs as soon as it was touched, flinched on being pinched, and in four minutes was as active as usual.

Exp. 5.—Three grains of chloroform were diffused in the jar of the capacity of 200 cubic inches, and a white mouse introduced. It was not affected at first, but in less than a minute became drowsy, and at the end of a minute appeared insensible, and did not move afterwards. It was allowed to remain two minutes longer; it breathed naturally, and its limbs were not relaxed. When taken out it was insensible to pinching; it began to recover voluntary motion in two minutes.

Exp. 6.—The same mouse was placed in the same jar on the following day, with 3·5 grs., being a grain and three-quarters for each 100 cubic inches. It ran round as before, but fell down in less than a minute, and before the end of the minute ceased to move. It continued breathing in its natural rapid manner till nearly four minutes had expired, when the breathing became very feeble, and immediately afterwards appeared to have ceased. The mouse was taken out just as four minutes had elapsed. It began immediately to give a few deep inspirations at intervals, after which the breathing became natural; it was perfectly insensible to pinching, and did not stir for three minutes. At the end of five minutes it seemed to be recovered, but it did not eat afterwards, and it died on the following day. The state of its organs will be mentioned farther on. The stoppage of respiration and impending death did not seem to be the direct effect of the vapour, but the result of continued and very deep insensibility.

Exp. 7.—A white mouse was placed in the same jar, with 4 grs. of chloroform. At the end of a minute it was lying, but moved its legs for a quarter of a minute longer. When four minutes had elapsed the breathing became slow, and it was taken out. It was totally insensible for the first three minutes after its removal, and recovered during the two following minutes.

Exp. 8.—The same mouse was placed in the same jar on the following day, with 4·5 grs. of chloroform, being $2\frac{1}{4}$ grs. for each 100 cubic inches. It became more quickly insensible, and at the end of two minutes the breathing was beginning to be affected, when it was taken out. It recovered in the course of five minutes.

Exp. 9.—A white mouse was put into this jar, after 5 grs. of chloroform had been diffused in it, being $2\frac{1}{2}$ grs. to each 100 cubic inches. It was totally insensible in three quarters of a minute; in a little more than a minute the breathing became difficult, and, before two minutes had expired, the respiration was on the point of ceasing, and it was taken out. The breathing remained difficult for five minutes, but in other five minutes the mouse recovered, and at the end of a quarter of an hour was very active.

It will be remarked that, in these experiments, the mice became much more quickly affected than the Guinea pigs. The reason of this is, their quicker respiration and much more diminutive size. In the last experiment, the quantity of vapour was evidently sufficient to arrest the breathing by its direct influence.

It is evident from the second, third, and fourth of the above experiments, that about one grain of chloroform to each 100 cubic inches of air, suffices to induce the second degree of narcotism, or that state in which the correct relation with the external world is abolished, but in which sensation and ill-directed voluntary movements may exist. Now one grain of chloroform produces 0·767 of a cubic inch of vapour of the sp. gr. 4·2, as given by Dumas; and when it is inhaled, it expands somewhat as it is warmed, from about 60° to the temperature of the body; but it expands only to the same extent as the air with which it is mixed, and therefore the proportions remain unaltered. But air, when saturated with vapour of chloroform at 100°, contains 43·3 cubic inches in 100; and

As 0·767 : 43·3 : : 0·0177 : 1

So that if the point of complete saturation be considered as unity, 0·0177, or 1-56th, will express the degree of

saturation of the air from which the vapour is immediately absorbed into the blood; and, consequently, also the degree of saturation of the blood itself.

I find that serum of blood at 100°, and at the ordinary pressure of the atmosphere, will dissolve about its own volume of vapour of chloroform; and since chloroform of sp. gr. 1·483 is 288 times as heavy as its own vapour, 0·0177 ÷ 288 gives 0·0000614, or one part in 16,285, as the average proportion of chloroform by measure in the blood, in the second degree of narcotism.

From the fifth experiment it appears that a grain and a half per 100 cubic inches of air is capable of producing the third degree of narcotism; and by the sixth and seventh experiments, it is shewn that from a grain and three-quarters to two grains causes a very complete state of insensibility, which cannot be long continued without danger; but I may remark, that four minutes in a mouse represents a much longer period in the human being, in whom the circulation and respiration are so much less rapid. I think we may take two grains as the average quantity capable of inducing the fourth degree,—the utmost extent of narcotism required, or that can be safely caused in surgical operations; and by the method of calculation above we shall get 0·0354, or 1-28th, as representing the degree of saturation of the blood, and 0·0001228 the proportion by measure in the blood.

A greater quantity than this seems to induce the fifth degree of narcotism, embarrassing the respiration; and two and a half grains have the power of directly stopping the respiratory movements. By calculation we obtain 0·0442, or 1-22nd, as the degree of saturation of the blood which has this effect.

Birds have generally a somewhat higher temperature than most mammalia, and therefore the following five experiments have been separated from the rest; but, in 13 and 14, the thermometer placed under the wing of the linnet, at the end of the experiment, indicated only 100°,—just the temperature in the groin of the Guinea pig when it was removed from the jar in the 4th experiment. These are the only occasions on which it occurred to me to apply the thermometer.

Exp. 10.—4·6 grs. of chloroform were put into a jar containing 920 cubic nches, by sliding the glass which covered it a little to one side. The jar was moved about to diffuse the vapour; and thus each 100 cubic inches of air contained half a grain. A hen chaffinch was introduced, by again momentarily sliding the cover a little to one side. In less than two minutes it seemed rather unsteady in its walking at the bottom of the jar, but no further effect was produced, although it remained twenty minutes; when taken out, indeed, it did not seem affected. This experiment was repeated on the same bird, and on another chaffinch, and also on a green linnet, with the same result; that is, no decided effect was produced.

Exp. 11.—9·2 grs. of chloroform were diffused through the air in the same jar, being one grain to each 100 cubic inches; and a chaffinch was put in. In less than two minutes it staggered about, and in two and a half minutes fell down, but still stirred. It did not get further affected, although it remained ten minutes. Sometimes it seemed perfectly insensible, but always stirred when the jar was moved, and occasionally it made voluntary efforts to stand. On being taken out it seemed sensible of its removal; it flinched on being pinched, and quickly recovered.

Exp. 12.—A chaffinch was placed in the same jar with 11·5 grs., being a grain and a quarter for each 100 cubic inches. In less than a minute it began to stagger, and shortly afterwards was unable to stand, but moved its legs and opened its eyes occasionally. It did not get further affected after two minutes had elapsed, although it remained three minutes longer. It seemed aware of its removal, but was not sensible to being pricked. In attempting to walk when placed on the table, immediately after its removal from the vapour, it fell forwards at every two or three steps. In a minute or two, however, it was able to walk.

Exp. 13.—A green linnet was put in the same jar, with 13·8 grs., being a grain and a half to each 100 cubic inches. In a minute it was unable to stand, and in half a minute more ceased to move. It remained breathing naturally, and kept its eyes open. It was taken out at the end of ten minutes, was insensible to having its foot

pinched, and began to recover voluntary motion in three minutes.

Exp. 14—Was performed on the same linnet, two or three days before the last, with a grain and three-quarters of chloroform to each 100 cubic inches, in the same jar. It was affected much in the same way as detailed above, but was longer in recovering voluntary motion after its removal, at the end of ten minutes.

It will be perceived that these results coincide as nearly as possible with the effects of the same quantities on the Guinea pigs and mice; and I found that when the quantity of chloroform exceeded two grains to the 100 cubic inches, birds were killed very rapidly.

It occurred to me that if this method of ascertaining the amount of vapour in the blood were correct, then a much more dilute vapour ought to suffice to produce insensibility in animals of cold blood; and that experimenting on them would completely confirm or invalidate these views.

The following experiment has been performed on frogs several times with the same result, the temperature of the room being about 55°.

Exp. 15.—4·6 grs. of chloroform were diffused through the jar of 920 cubic inches capacity, as in Exp. 10. In the course of a few minutes the frog began to be affected, and at the end of ten minutes was quite motionless and flaccid; but the respiration was still going on. Being now taken out, it was found to be insensible to pricking, but recovered in a quarter of an hour. In a repetition of this experiment, in which the frog continued a few minutes longer, the respiration also ceased, and the recovery was more tardy. On one occasion the frog was left in the jar for an hour, but when taken out and turned over, the pulsations of the heart could be seen. In an hour after its removal it was found to be completely recovered.

Now the vapour is absorbed into the blood of the frog at the temperature of the external air, whose point of saturation, therefore, remains unaltered; and as half a grain of chloroform produces 0·383 cubic inches of vapour; and air at 55° will contain, when saturated, 10 per cent. of vapour; 0·0383, or 1-26th, expresses the degree of saturation of the air, and also of the blood of the frog. And this is a little more than 0·0354, or 1-28th, which we considered as the greatest quantity that could with safety exist in the blood. But frogs are able to live without pulmonary respiration, by means of the action of the air on the skin: consequently this experiment coincides exactly with the others, and remarkably confirms the accuracy of this method of determining the amount of chloroform in the blood.

At the College of Physicians, on March 29, when I had the honour of shewing the effects of chloroform at Dr. Wilson's Lumleian Lectures, and briefly explained these views, I conjoined the last experiment and the 10th in the following manner. I introduced a chaffinch, in a very small cage, into a glass jar holding nearly 1000 cubic inches, and put a frog into the same jar, covered it with a piece of glass, and dropped 5 grs. of chloroform on a piece of blotting paper suspended within. In less than ten minutes the frog was insensible, but the bird was unaffected. Then, in order to shew that the effects depended entirely on the dilution of the vapour, another frog, and another small bird, were placed in a jar containing but 200 cubic inches, with exactly the same quantity of chloroform. In about a minute and a half they were both taken out,—the bird totally insensible, but the frog not appreciably affected, as from its less active respiration it had not had time to absorb much of the vapour.

As the narcotism of frogs, by vapour too much diluted to affect animals of warm blood, depends merely on their temperature, it follows that, by warming them, they ought to be put into the same condition, in this respect, as the higher classes of animals; and although I have not raised their temperature to the same degree, I have found that as it is increased, they cease to be affected by dilute vapour that would narcotise them at a lower temperature.

Exp. 16.—I placed the jar holding 920 cubic inches near the fire, with a frog and a thermometer in it; and when the air within reached 75°, 4·6 grains of chloroform were diffused through it. The jar was kept for twenty minutes, with the thermometer indicating the same temperature within one degree. For the first seventeen minutes the frog was unaffected, and

only was dull and sluggish, but not insensible when taken out.

Experiments with Ether.

We will now proceed to consider ether, and will begin with the brief relation of a few experiments, shewing the strength of its vapour required to produce narcotism to various degrees.

Exp. 17.—Two grains of ether were put into a jar holding 200 cubic inches, and the vapour diffused equally, when a tame mouse was introduced, and allowed to remain a quarter of an hour, but it was not appreciably affected.

Exp. 18.—Another mouse was placed in the same jar, with three grains of ether, being a grain and a half to each 100 cubic inches. In a minute and a half it was unable to stand, but continued to move its limbs occasionally. It remained eight minutes without becoming further affected. When taken out it was sensible to pinching, but fell over on its side in attempting to walk. In a minute and a half the effect of the ether appeared to have gone off entirely.

Exp. 19.—A white mouse in the same jar, with four grains of ether, was unable to stand at the end of a minute, and at the end of another minute ceased to move, but continued to breathe naturally, and was taken out at the end of five minutes. It moved on being pinched, began to attempt to walk at the end of a minute, and in two minutes more seemed quite recovered.

Exp. 20.—Five grains of ether, being two and a half grains to each 100 cubic inches, were diffused throughout the same jar, and a mouse put in. It became rather more quickly insensible than the one in the last experiment. It was allowed to remain eight minutes. It moved its foot a very little when pinched, and recovered in the course of four minutes.

Exp. 21.—A white mouse was placed in the same jar with six grains of ether. In a minute and a half it was lying insensible. At the end of three minutes the breathing became laborious, and accompanied by a kind of stertor. It continued in this state till taken out, at the end of seven minutes, when it was found to be totally insensible to pinching. The breathing improved at the end of a minute; it began to move at the end of three minutes; and five minutes after its removal it had recovered.

Exp. 22.—The same mouse was put into this jar on the following day, with seven grains of ether, being 3·5 grs. to the 100 cubic inches. Stertorous breathing came on sooner than before; it seemed at the point of death when four minutes had elapsed; and being then taken out, was longer in recovering than after the last experiment.

Exp. 23.—Two or three days afterwards the same mouse was placed in the jar, with eight grains of ether, being four grains for each 100 cubic inches. It became insensible in half a minute. In two minutes and a half the breathing became difficult, and at a little more than three minutes it appeared that the breathing was about to cease, and the mouse was taken out. In a minute or two the breathing improved, and in the course of five minutes from its removal it had recovered.

The temperature of the mice employed in the above experiments was about 100°. That of the birds in the following experiments was higher, as is stated; and they differ widely from the mice in the strength of vapour required to produce a given effect, although I found but little difference between the mice and birds, in this respect, in the former experiments on chloroform. And one of the linnets was employed in both sets of experiments. Having seen MM. Dumeril and Demarquay's statement of the diminution of animal temperature from inhalation of ether and chloroform, before the following experiments were performed, the thermometer was applied at the beginning and conclusion of some of them. I have selected every fourth experiment from a larger series on birds.

Exp. 24.—18·4 grs. of ether were diffused through a jar holding 920 cubic inches, being two grains to each 100 cubic inches; and a green linnet was introduced. After two or three minutes it staggered somewhat, and in a few minutes more appeared so drowsy, that it had a difficulty in holding up its head. It was taken out at the end of a quarter of an hour, quite sensible, and in a minute or two was able to get on its perch. The temperature under the wing was 110° before the experi-

ment began, and the same at the conclusion.

Exp. 25.—Another linnet was placed in the same jar, with four grains of ether to each 100 cubic inches of air. In two minutes it was unable to stand, and in a minute more voluntary motion had ceased. It lay breathing quietly till taken out, at the end of a quarter of an hour. It moved its foot slightly when it was pinched. In three minutes it began to recover voluntary motion, and was soon well. The temperature was 110° under the wing, when put into the jar, and 105° when taken out.

Exp. 26.—A green linnet was put into the same jar with 55·2 grs. of ether, being six grains to the 100 cubic inches. It was insensible in a minute and a half, and lay motionless, breathing naturally, till taken out at the end of a quarter of an hour. It moved its toes very slightly when they were pinched with the forceps, and it began to recover voluntary motion in two or three minutes. Temperature 110° before the experiment, and 102° at the end.

Exp. 27.—A linnet was placed in the same jar, containing eight grains of ether to each 100 cubic inches. Voluntary motion ceased at the end of a minute. The breathing was natural for some time, but afterwards became feeble, and at the end of four minutes appeared to have ceased; and the bird was taken out, when it was found to be breathing very gently. It was totally insensible to pinching. The breathing improved, and it recovered in four minutes.

Exp. 28.—9·2 grs. of ether, being one grain to each 100 cubic inches of air, were diffused through the jar holding 920 cubic inches of air, and a frog was introduced. At the end of a quarter of an hour it had ceased to move spontaneously, but could be made to move its limbs, by inclining the jar so as to turn it over. At the end of half an hour voluntary motion could no longer be excited, and the breathing was slow. It was removed at the end of three-quarters of an hour, quite insensible, and the respiratory movements being performed only at long intervals, but the heart beating naturally; and it recovered in the course of half an hour. The temperature of the room was 55° at the time of this experiment.

We find from the 18th experiment, that a grain and a half of ether for each 100 cubic inches of air, is sufficient to induce the second degree of narcotism in the mouse; and a grain and a half of ether make 1·9 cubic inches of vapour, of sp. gr. 2·586. Now the ether I employed boiled at 96°. At this temperature, consequently, its vapour would exclude the air entirely; and ether vapour in contact with the liquid giving it off, could only be raised to 100° by such a pressure as would cause the boiling point of the ether to rise to that temperature. That pressure would be equal to 32·4 inches of mercury, or 2·4 inches above the usual barometrical pressure; and the vapour would be condensed somewhat, so that the space of 100 cubic inches would contain what would be equivalent to 108 cubic inches at the usual pressure. This is the quantity, then, with which we have to compare 1·9 cubic inches, in order to ascertain the degree of saturation of the space in the air-cells of the lungs, and also of the blood; and by calculation, as when treating of chloroform,

1·9 is to 108 as 0·0175 is to 1.

So that we find 0·0175, or 1-57th, to be the amount of saturation of the blood by ether necessary to produce the second degree of narcotism; and as by Exp. 21, three grains in 100 cubic inches produced the fourth degree of narcotism, we get 0·035, or 1-28th, as the amount of saturation of the blood in this degree. Now this is within the smallest fraction of what was found to be the extent of saturation of the blood by chloroform, requisite to produce narcotism to the same degrees. But the respective amount of the two medicines in the blood differs widely; for whilst chloroform required about 288 parts of serum to dissolve it, I find that 100 parts of serum dissolve 5 parts of ether at 100°; consequently $0·05 \times 0·0175$ gives 0·000875, or one part in 1142, as the proportion in the blood in the second degree of narcotism, and $0·05 \times 0·035$ gives 0·00175, or one part in 572, as the proportion in the fourth degree.

In Exp. 28, the frog was rendered completely insensible by vapour of a strength which was not sufficient to produce any appreciable effect on the mouse in Exp. 17. This is in accord-

ance with what was met with in the experiments with chloroform. Air, when saturated with ether at 55°, contains 32 grains; so that the blood of the frog might contain 1-32d part as much as it would dissolve, which, although not quite so great a proportion as was considered the average for the fourth degree in the mice, yet was more than sufficient to render insensible the mouse in Exp. 20.

There is a remarkable difference between the birds and the mice in respect to the proportions of ether and air required to render them insensible, a difference that was not observed with respect to chloroform. In some experiments with ether on Guinea pigs, which are not adduced, they were found to agree with mice in the effects of various quantities.

The birds were found to require nearly twice as much: five grains to 100 cubic inches, the quantity used in an experiment between the 25th and 26th, which is not related, may be taken as the average for the fourth degree of narcotism in these birds, with a temperature of 110°. By the kind of calculation made before, we should get a higher amount of saturation of the blood than for the same degree in the mice. But as serum at 110° dissolves much less ether than at 100°, the quantity of this medicine in the blood of birds is not greater than in that of other animals; and considered in relation to what the blood would dissolve at 100°, the degree of saturation is the same.

By Expts. 22, 23, and 27, we find that with ether as with chloroform, a quantity of vapour in the air somewhat greater than suffices to induce complete narcotism has the effect of arresting the respiratory movements. The exact amount which has this effect might be determined if necessary.

Before proceeding to consider some other vapours, and the general conclusions to be drawn from these inquiries, it may be as well to consider how far the above results coincide with experience as to the quantities of chloroform and ether required to produce insensibility in the human subject.

The blood in the human adult is calculated by M. Valentin to average about 30 pounds. This quantity would contain 26 pounds five ounces of serum, which, allowing for its specific gravity, would measure 410 fluid ounces. This being reduced to minims, and multiplied by 0·0000614, the proportion of chloroform in the blood required to produce narcotism to the second degree, gives 12 minims as the whole quantity in the blood. And to produce narcotism to the fourth degree we should have twice as much, or 24 minims. More than this is used in practice, because a considerable portion is not absorbed, being thrown out again when it has proceeded no further than the trachea, the mouth and nostrils, or even the face-piece. But I find that if I put twelve minims into a bladder containing a little air, and breathe it over and over again, in the manner of taking nitrous oxide, it suffices to remove consciousness, producing the second degree of its effects.

In order to find the whole quantity of ether in the blood, we may multiply 410, the number of fluid ounces of serum, by 0·000875 for the second degree, and by 0·00175 for the fourth degree, when we shall obtain 0·358 and 0·71 of an ounce, *i. e.* f℥ij. ♏l. in the first instance, and f℥v. ♏xl. in the second,—quantities which agree very well with experience when we allow for what is expired without being absorbed.

Experiments to determine the quantity in the blood, and illustrate the action of nitric ether, bisulphuret of carbon, and benzin.

Nitric ether, or nitrate of the oxide of ethyle, consists of nitric acid combined with ordinary or sulphuric ether. It is described as a colourless liquid of sp. gr. 1·112, with a sweet taste and pleasant smell, and boiling at 185° Fah. Two specimens of it which I have answer to this description. One was made and presented to me by Mr. Bullock; and the other, which was made by Mr. Joseph Spence, was given to me by Dr. Barnes. Dr. Chambert, of Paris, related some experiments that he had performed on dogs with the vapour of this substance, in a work on Ether, published in autumn last; and Dr. Simpson afterwards mentioned it in his pamphlet on Chloroform, as one of the things that he had tried.

The two following experiments will serve to determine the quantity of nitric ether in the blood, when insensibility is induced by it:—

Exp. 29.—Four grains were diffused through the air in a jar containing 800 cubic inches; and a common mouse was introduced in the same manner as in the preceding experiments. In ten minutes it became rather torpid, but could be disturbed by touching the jar. It was left in this condition when it had been in a quarter of an hour. On returning at the end of an hour from the commencement of the experiment, I found the mouse lying still. It was taken out, and it moved spontaneously, endeavouring to walk, but falling over; it was quite sensible to being pinched. In five minutes it had recovered power to walk, but was not yet conscious of danger, as it would have walked off the table if not prevented. In a few minutes longer it had recovered its usual state.

Exp. 30.—Another mouse was placed in the same jar with eight grs. of nitric ether. It became affected in ten minutes, and at the end of a quarter of an hour had ceased to move, but lay breathing naturally 160 times in the minute. It remained in this state till removed half an hour after the commencement of the experiment, when it was found to be relaxed, and totally insensible. It began to move in ten minutes; it could walk at the end of a quarter of an hour, and in a little time longer was quite active.

We perceive from the above experiments that half a grain of nitric ether to each 100 cubic inches of air suffices to induce the second degree of narcotism, and one grain the fourth degree. I have not met with a statement of the specific gravity of the vapour of this ether in any work to which I have referred, and consequently I endeavoured to determine it myself—not with great nicety, but with sufficient accuracy to satisfy the purpose of this inquiry. I made it to be 5·67; and half a grain of vapour of this specific gravity will be found on calculation to occupy 0·284 of a cubic inch. The quantity of this vapour in 100 cubic inches of air saturated with it at 100°, is 15·7 cubic inches, and $0{\cdot}284 \div 15{\cdot}7$ will give 0·018, or rather less than one fifty-fifth, as the relative saturation of the blood with nitric ether in the second degree of narcotism. One grain produces 0·568 of a cubic inch of vapour: and this, divided by 15·7, gives 0·0361, or very nearly one twenty-eighth, as the relative saturation of the blood in the fourth degree of narcotism. So we find that the quantity of the vapour in the blood, viewed in relation to what it would dissolve, is the same as in the cases of chloroform and sulphuric ether. In some experiments on birds, a rather larger quantity of vapour was required; but when their higher temperature was taken into account the relative proportion to what the air would take up was found to be the same, and, consequently, their blood was saturated to just the same extent.

One part by measure of nitric ether requires 52 parts of serum at 100° to dissolve it, and $52 \times 56 = 2912$; consequently, one part in 2912 is the proportion in the blood in the second degree of narcotism; and considering the average quantity of serum in the body, as before, to be 410 fluidounces, we get by calculation 67 minims as the whole quantity in the blood in this degree; and twice as much, or 2 drachms and 14 minims, in the fourth degree. These quantities agree with the little experience I have had of its effects on the human subject.

From its slight pungency, and the gradual way in which, owing to its sparing volatility, its effects are pro-

duced, nitric ether would be a very safe anæsthetic, suitable for minor surgical operations if its effects were agreeable, but such is apparently not always the case. M. Chambert met with vomiting in most of the dogs to which he gave it, and was deterred from inhaling it himself. Dr. Simpson states, in the Monthly Journal of April last, that he had found it to produce sensations of noise and fulness in the head before insensibility, and, usually, much headache and giddiness afterwards. I have inhaled a small quantity of it on two or three occasions, and it caused a disagreeable feeling of sickness each time. I have given it only to one patient, but in that instance it acted very favourably. A middle-aged man applied at St. George's Hospital, on May 26, to have a tooth extracted. He inhaled from the apparatus I use for chloroform. Soon after he began his pulse became accelerated and increased in force, and his face rather flushed. He continued to inhale steadily for three minutes, when I found that the sensibility of the conjunctiva was considerably diminished, although voluntary motion continued in the eyes and eyelids, the expression of his countenance not being altered from that of complete consciousness; and he held his head upright. The vapour was left off, and the tooth, which was firmly fixed, was taken out by Mr. Price, the dresser for the week, without any sign of the operation being felt; the man holding his mouth wide open in an accommodating manner. A minute afterwards he began to spit on the floor; and being questioned, he said that he had no knowledge of the removal of the tooth, and should have thought that he had never lost his senses, except for what he found had been done. His feelings were not unpleasant whilst inhaling, and he felt well, and walked away in a few minutes afterwards. A fluid-drachm and a half was employed, and it was not all used. There was perfect immunity from pain, whilst the narcotism of the nervous centres was not carried further than the second degree: this, however, I do not look on as a peculiarity of nitric ether, for I have met with it occasionally from chloroform and sulphuric ether when the vapour was introduced slowly. The above case, I think, affords encouragement for further trials of this medicine.

Bisulphuret of Carbon.

This substance is well known to every one at all conversant with chemistry. It is a transparent colourless liquid, of sp. gr. 1·272, having a very fœtid odour, and boiling at about 113°. A paragraph copied from the Morgenblad went the round of the journals of this country about the end of February last, stating that M. Harald Thanlow, of Christiana, in Norway, had discovered a substitute for chloroform and ether, in a sulphate of carbon, a very cheap substance made from sulphur and charcoal. This, of course, could be nothing else than the bisulphuret of carbon. I immediately examined its effects on animals, and found that it causes convulsive tremors, but that the kind of narcotism such as ether produces may be recognised. On account of the great volatility and very sparing solubility of this substance, the point of relative saturation of the blood by it is soon reached.

The following experiments will shew both the action of the vapour and the quantity of it in the blood.

Exp. 31.—Two grains of bisulphuret of carbon were diffused through the air in a jar holding 200 cubic inches, and a white mouse was introduced. In three minutes it was altered in its manner, and no longer regarded the approach of the hand towards it. In six minutes tremors came on, which soon became violent, and lasted till after the mouse was taken out at the end of ten minutes; but voluntary motion continued along with the tremors. When taken out, it flinched on being pinched; attempted to walk, but fell over on its side: it had no appreciation of danger at first, but it quickly recovered.

Exp. 32.—A common mouse was put into a jar holding 800 cubic inches, in which 12 grains of bisulphuret of carbon had been diffused, being a grain and a half to each 100 cubic inches. In a minute it began to have convulsive tremors whilst still walking. In half a minute more, voluntary motion ceased, but the tremors continued. It was removed at the end of ten minutes, was sensible to pricking and pinching, and in a minute or two began to recover voluntary motion, the trembling of the whole body continuing for a little time after it was able to walk.

Exp. 33.—A white mouse was placed in the jar of 200 cubic inches capacity, with four grains of this substance in the form of vapour. It became quickly affected, and was lying powerless in less than half a minute. Convulsive tremors came on immediately after it fell, and lasted till death. At the end of four minutes the breathing became difficult, being performed only by distant convulsive efforts. The mouse was immediately removed, but only gave one or two gasps afterwards.

In another experiment, in which there were two and a quarter grains to each 100 cubic inches of air, the mouse, after running about for a minute, fell down, and stretched itself violently out, and died.

There is no stage of muscular relaxation prior to death by this vapour, as by those we have previously considered, when their effects are gradually induced; but tremulous convulsions of the whole body continue till death, which seems to be threatened almost as soon as complete insensibility to external impressions is established.

In Exp. 31, narcotism to the second degree was occasioned by one grain to 100 cubic inches. The sp. gr. of the vapour of bisulphuret of carbon being 2·668, it will be found that one grain of the liquid must produce 1·209 cubic inches of vapour; and I find that air, when saturated with it at 100°, expands to four times its former volume, so that 100 cubic inches contain 75 of vapour. Therefore 1·209÷75 gives 0·0161, or one part in 62 of what the blood would dissolve, as the relative saturation of the blood in the second degree of narcotism; and, as Exp. 33 may be regarded as the nearest approach to the fourth degree that we can get with this vapour, twice as much, or one part in 31, is the relative amount for that degree. These proportions do not differ much from those arrived at in the inquiries concerning the vapours previously examined.

Serum at 100° dissolves, as nearly as I can determine, just its own volume of the vapour of bisulphuret of carbon; and, as the liquid is 408 times as heavy as its own vapour at the temperature of 100°, it will be found, by a similar calculation to that made with respect to the vapours treated of previously, that about 7½ minims is the average quantity that there should be in the whole blood of the human subject in the second degree, and 15 minims in the fourth degree of narcotism. When the great volatility of this substance is also taken into account, it will be perceived that its effects, when inhaled, must be most powerful. Indeed, I feel convinced, that, if a person were to draw a single deep inspiration of air, saturated with its vapour at a summer temperature, instant death would be the result. Although its odour is offensive, it is not difficult to inhale; and Dr. Simpson has given it in a surgical operation and an obstetric case; he also informs us (op. cit.) that its effects were so powerful and so transient, that it was very unmanageable, and that it also caused some unpleasant symptoms, and he does not recommend its use.

Benzin or Benzole.

This substance was first discovered by Dr. Faraday, as a product of the distillation of compressed oil-gas, and named bicarburet of hydrogen; it was afterwards obtained by Mitscherlich, by distilling a mixture of benzoic acid and slaked lime; latterly Mr. Blatchford Mansfield has obtained it by the distillation of coal-tar. It consists of carbon and hydrogen, as its first name implied, the proportions being $C_{12} H_6$. It is a clear, colourless, and very mobile liquid, of sp. gr. 0·85, and having an aromatic odour. It has been described as boiling at 186°, but some which Mr. Bullock made from benzoic acid, and carefully rectified, boiled at 180°; and a portion with which Mr. Mansfield favoured me, boils, as he always found it to do, about 178°. There is no difference either in sensible properties or physiological effects between the benzin made from benzoic acid, and that obtained from coal-tar. Like the substance last treated of, it causes convulsive tremors in addition to the other symptoms of narcotism; they usually begin in animals before voluntary motion ceases, and continue as long as the vapour is applied, and during part of the recovery, and until death when animals are killed by it. The tremors are usually violent, affecting the whole body, and accompanied in birds with flapping of the wings.

One experiment will suffice to shew the effects of this vapour.

Exp. 34.—Six grains of benzin were diffused through the air in a jar holding 800 cubic inches, being three-quar-

ters of a grain for each 100 cubic inches; and a half-grown white mouse was introduced. In less than a minute it began to shake and tremble, and ceased to move voluntarily, but every now and then gave a sudden start; this start could also be occasioned at any time by striking the jar so as to make a noise. This mouse continued in the same state till removed at the end of a quarter of an hour; it was totally insensible to pricking and pinching, which produced not the slightest effect on it, whilst at the same time a sharp noise near it caused it to start. Five minutes after its removal it began to recover voluntary motion, but the tremors continued a little longer. The mouse was soon as well as before the experiment. Less than half a grain of benzin to each 100 cubic inches of air, suffices to impair the voluntary motion, and alter the manner of an animal; rather more than half a grain causes convulsive tremors, and three-quarters of a grain and upwards produces complete insensibility, whilst two grains will take away life. In the experiment related above, the fourth degree of narcotism appeared to be induced by three-quarters of a grain, but one grain to the 100 cubic inches of air is the average quantity for that stage in several experiments. The specific gravity of the vapour of benzin being 2·738, one grain of the liquid makes 1·179 cubic inch of vapour; and I find that air saturated with it at 100°, contains 20 per cent. of it by measure: so 1·179÷20 will give the relative saturation of the blood. It is 0·058, or one-seventeenth part of what it would dissolve. This is a greater proportion than we arrived at in examining the vapours treated of above.

Benzin requires 270 parts of serum for its solution; consequently, by the kind of calculation made before, 42 minims is obtained as the average quantity that there would be in the human body, if narcotism were carried to the fourth degree by this vapour. It follows from this that benzin must be powerful in its effects, and such I have found to be the case, but they are not so rapidly produced as the effects of chloroform, on account of its lesser volatility. I employed it in some cases of tooth-drawing, and in one amputation, in St. George's Hospital, at the latter part of last year. Its action in the minor operations was very nearly the same as that of nitric ether, in the case related above; but in the amputation, where its effects were carried further, the patient had violent convulsive tremors for about a minute, which, although not followed by any ill consequences, were sufficiently disagreeable to deter me from using it again, or recommending it in the larger operations.

Bromoform.

This is a volatile liquid of the same composition as chloroform, except that three atoms of bromine occupy the place of the same proportion of chlorine. It is made in the same way as chloroform, bromide of lime being used instead of chloride. I have repeatedly made it, but have never succeeded in obtaining more than a few grains in a purified state, although I used an ounce of bromine in making the bromide of lime on each occasion; consequently it is very expensive. It is extremely fragrant, having an odour that is, in my opinion, much pleasanter than that of chloroform or any other of this class of substances with which I am acquainted. It boils at about 184° Fah.; but, as its vapour is twice as heavy as that of chloroform, it is in point of fact nearly as volatile as that liquid. It is very pleasant to inhale, but I have never breathed more than a few grains at a time, and, therefore, cannot speak of its operation on the human subject. Its effects on animals closely resemble those of chloroform.

The two following experiments will serve to illustrate the action of bromoform, and to determine the quantity in the blood:—

Exp. 35.—A common mouse was placed in a jar containing 400 cubic inches, in which three grains of bromoform had been diffused. In the course of four or five miuntes it became unsteady in its walking, and ceased to regard objects in its way. It did not get further affected, except to become rather sluggish, and, when removed at the end of twenty minutes, was capable of voluntary motion. It did not regard a slight pinch, but flinched when the soft part of its foot was pinched severely. It recovered gradually, and was pretty well re-established in half an hour.

Exp. 36.—Another mouse was placed in the same jar with six grains of bromoform: it was more quickly affected,

and, at the end of five minutes, all voluntary motion had ceased, and it lay breathing naturally and rather deeply. It was removed at the end of a quarter of an hour, and did not stir on being pinched. It began to recover voluntary motion in ten minutes, but staggered at first. In a little more than half an hour it had recovered.

In the first of these experiments the second degree of narcotism was caused by three-quarters of a grain of bromoform to each 100 cubic inches of air. The specific gravity of the vapour of bromoform is stated, in Thompson's Chemistry of Organic Bodies, to be 8·785, which gives 0·275 of a cubic inch as the quantity of vapour that three-quarters of a grain would yield; and I find that fifteen cubic inches of this vapour are contained in 100 of air saturated with it at the temperature of 100°; consequently the air of the jar contained $0{\cdot}275 \div 15 = 0{\cdot}0183$, or nearly one fifty-fourth part of what it would take up if saturated at 100°, and, according to the principles explained in a former part of these papers,* the blood of the mouse would contain just the same proportion—one fifty-fourth of what it could dissolve. In the other experiment, the fourth degree of narcotism was produced by twice the quantity—a grain and a half to each 100 cubic inches, which, by the same computation, gives about one twenty-seventh part of what the blood would take up. These proportions are nearly the same as in the case of most of the substances previously examined. I have not ascertained the exact solubility of bromoform, and consequently cannot compute the absolute quantity in the blood, but it resembles chloroform in being very sparingly soluble.

I have not heard that any one else has examined the effects of the vapour of bromoform; but Dr. Glover mentions an experiment in his valuable paper On Bromine and its Compounds,† in which bromoform in the liquid state was introduced into the stomach of a rabbit, with the same results as in other experiments with similar bodies: these were death, with congestion of the lungs and stomach.

Bromide of Ethyle.

Bromide of ethyle, or hydrobromic ether, is a very volatile liquid, boiling, as I have found, at 104°. It has a pleasant but somewhat pungent taste and smell. It was discovered by Serullas in 1827, and is formed by the action of phosphorus on a solution of bromine in alcohol. I am not aware that its physiological effects have been examined except in a few experiments which I have performed with its vapour. I will cite two of them to illustrate its effects. The bromide of ethyle was made by myself.

Exp. 37.—Eight grains of bromide of ethyle were introduced into a jar containing 400 cubic inches, and the vapour which instantly resulted was equally diffused by moving the jar. A mouse was then put in. In about four minutes it began to stagger and fall over, and was quite regardless of external objects. It did not get affected beyond this extent, except that it became rather feeble. It was taken out at the end of a quarter of an hour, having the power of voluntary motion, but rolling over in its attempts to walk. It flinched with severe, but not with slight pinching. In ten minutes it had pretty well recovered.

Exp. 38.—Another mouse was placed in the same jar with sixteen grains of bromide of ethyle. In two minutes it had ceased to move, not having shewn any signs of excitement. It lay motionless, breathing at first deeply, afterwards more naturally. It was removed at the end of a quarter of an hour, and was found to be totally insensible. In five minutes it began to move, but rolled over in its first attempts to walk. Twenty minutes after its removal, it appeared to have recovered from the effects of the vapour.

Connected with the great volatility of this liquid is the increased quantity of it required to be present in the air to produce a given effect,—in accordance with the law which requires that the blood must be impregnated to a certain extent relatively to what it could imbibe. In one experiment I performed with this substance, one grain to each 100 cubic inches of air produced no appreciable effect whatever on a mouse confined for twenty minutes in it, although with that quantity of several less volatile bodies complete insensibility would have been induced.

In experiment 37 two grains to each 100 cubic inches of air produced the

* Vol. xli. p. 850.
† Edin. Med. and Surg. Jour., Oct. 1842.

second degree of narcotism; and in the following experiment four grains produced the fourth degree. The specific gravity of the vapour of bromide of ethyle is, I find, 3·78, the atom being represented by two volumes. Two grains will consequently occupy 1·706 cubic inches in the form of vapour. At the temperature of 100° the vapour of bromide of ethyle almost excludes the air, and occupies 92 8 per cent. of its place. So 1·706÷92·8 gives 0·0183, or nearly one fifty-fourth, as the relative saturation of the blood with this vapour for the second degree of narcotism; and there would be twice as much, or one twenty-seventh, for the fourth degree.

I have not ascertained by direct experiment how much bromide of ethyle serum will dissolve, but I find that water dissolves about one-sixtieth of its volume of it; and as the solubility of liquids of this kind is nearly the same in water as in serum, this may safely be taken as the standard;—when, if we consider the average quantity of serum in the human body to be 410 fluid ounces, as in a former part of these papers, and make the kind of calculation there made, we shall find that one fluid drachm and ten minims is the average quantity that there would be in the blood of a human subject in the second degree of narcotism; and two drachms and twenty minims in the fourth degree.

Dutch Liquid.

In recent works on chemistry this substance is called the hydrochlorate of chloride of acetyle. It is formed by the combination of equal volumes of olefiant gas and chlorine. It has a taste at once sweet and hot, and a pungent ethereal odour. It boils at 180°, and not at 148°, as Dr. Simpson states in some brief remarks on it in the Edinburgh Monthly Journal for April last, where he informs us that its vapour, when inhaled, causes so great irritation of the throat that few persons can persevere in inhaling it long enough to produce anæsthesia; but that he had, however, "seen it inhaled perseveringly until this state, with all its usual phenomena, followed; and without excitement of the pulse or subsequent headache." My experiments with it have been confined to animals; and the two following will serve as a sample of them:—

Exp. 39.—One grain and a half of Dutch liquid was diffused through the air of a jar containing 400 cubic inches, and a mouse was introduced. After ten minutes had elapsed it began to stagger in its walk, and it continued to do so till it was removed at the end of half an hour. It was occasionally lying still, but always began to walk in an unsteady manner when the jar was moved. It was sensible to pinching on its removal, and in a quarter of an hour had recovered from its inebriation. It continued well.

Exp. 40.—A mouse was put into the same jar after three grains of Dutch liquid had been diffused in it. It began to stagger sooner than that employed in the last experiment; and at the end of ten minutes had ceased to move, without having had any struggling or rigidity; and it was not disturbed on the jar being moved. It lay breathing naturally till it was taken out at the end of half an hour, when it was found to be totally insensible to pinching. In ten minutes after its removal it began to move, but rolled over in its efforts to walk; when half an hour had elapsed it appeared to have recovered entirely from the narcotism, but was less lively than before; and two or three hours afterwards it was observed to be suffering with difficulty of breathing, and it died in the course of the day. The lungs were congested and of a deep vermilion colour, probably the result of inflammation, occasioned by the irritating nature of the vapour. The right cavities of the heart were distended with dark-coloured coagulated blood. The same appearances were met with in another mouse that died in the same way after breathing this vapour.

In the first of these two experiments the second degree of narcotism was effected by three-eighths of a grain of vapour to each 100 cubic inches of air; and as the specific gravity of this vapour is 3·4484, three-eighths of a grain must occupy 0·35 of a cubic inch. I find that air, when saturated with vapour of Dutch liquid at 100°, contains 17·5 per cent., and therefore 0·35÷17·5 gives 0·02, or one-fiftieth, as the relative saturation of the blood in this degree. In the other experiment the fourth degree of narcotism was caused by twice as much vapour, or three-quarters of a grain to each 100 cubic inches, and, consequently, the blood would

contain twice as much, or one twenty-fifth part of what it would hold in solution if saturated. I have ascertained that Dutch liquid requires about 100 parts of water for its solution, and taking its solubility in the serum to be the same, the blood would contain one part in 5000 in the second, and one part in 2500 in the fourth degree of narcotism, which in the human subject would be, on an average, 46 minims and 92 minims respectively.

General results of the experiments.

We have now seen the result of this experimental inquiry into the action of eight volatile substances, viz.: chloroform, ether, nitrate of oxide of ethyle, bisulphuret of carbon, benzin, bromoform, bromide of ethyle, and Dutch liquid. We find that the quantity of each substance in the blood, in corresponding degrees of narcotism, bears a certain proportion to what the blood would dissolve—a proportion that is almost exactly the same for all of them, with a slight exception in the case of benzin, which I believe is more apparent than real. The actual quantity of the different substances in the blood, however, differs widely; being influenced by their solubility. When the amount of saturation of the blood is the same, then it follows that the quantity of vapour required to produce the effect must increase with the solubility, and the effect produced by a given quantity must be in the inverse ratio of the solubility, as I announced some time ago.* This rule holds good with respect to all the substances of this kind that I have examined; including, in addition to those enumerated in this paper, bichloride of carbon, iodide of ethyle, acetate of oxide of ethyle, nitrate of oxide of methyle, acetate of oxide of methyle, pyroxilic spirit, acetone, and alcohol. The exact proportion in the blood, in the case of the three last mentioned, cannot be ascertained directly by experiments of the kind detailed above; for, being soluble to an unlimited extent, they continue to be absorbed as long as the experiment lasts: but from the large quantity of these substances that is required to produce insensibility, they confirm the rule stated above in a remarkable manner.

This general law, of course, does not apply to all narcotics; not, for instance, to hydrocyanic acid, but only to those producing effects analogous to what are produced by ether, and having, I presume, a similar mode of action. I am not able at present to define them better than by calling them, that group of narcotics whose strength is inversely as their solubility in water (and consequently in the blood). In estimating their strength, when inhaled in the ordinary way, another element has to be taken into the account, viz., their volatility; for that influences the quantity that would be inhaled. By multiplying together the number of parts of water that each substance requires for its solution, and the number of minims of each substance that air will hold in solution at 60°, we get a set of figures expressive of the relative strength of each, when breathed in the ordinary way; and by another method of calculation the time might be expressed, in minutes and seconds, that it would take, on an average, to render persons, breathing in the usual way, insensible by each substance: but I shall here confine myself to enumerating the bodies I have examined in two columns; arranging them, in the first column, in the inverse order of their solubility, which is the direct order of their actual potency; and in the second column, in the order in which they stand after their volatility is taken into the account, which is the order of their potency when mixed with air till it is saturated at any constant temperature.

Bisulphuret of Carbon	Bisulphuret of Carbon
Bichloride of Carbon	Chloroform
Chloroform	Bichloride of Carbon
Bromoform	Bromoform
Benzin	Bromide of Ethyle
Dutch Liquid	Benzin
Iodide of Ethyle	Iodide of Ethyle
Bromide of Ethyle	Dutch Liquid
Nitrate of Oxide of Ethyle	Oxide of Ethyle (Ether)
Nitrate of Oxide of Methyle	Nitrate of Oxide of Ethyle
Oxide of Ethyle (Ether)	Nitrate of Oxide of Methyle
Acetate of Oxide of Ethyle	Acetate of Oxide of Ethyle
Acetate of Oxide of Methyle	Acetate of Oxide of Methyle
Acetone	Acetone
Pyroxilic Spirit	Pyroxilic Spirit
Alcohol	Alcohol

* MEDICAL GAZETTE, March 31.

The general law, stated above, respecting the solubility of these liquids in the blood, applies also, with certain modifications, to a number of bodies which are gaseous at ordinary temperatures, and there are several important conclusions to be deduced from it. But before proceeding further in the attempt to give a general history of narcotic vapours and gases, and to determine what substances should be included in the list or otherwise, it will be well for me to describe, more particularly than I have done, the nature of the narcotism produced by the class of bodies we are considering, of which chloroform may very properly be taken as the type. I shall, therefore, next proceed to give the best description that I can of the effects of chloroform, having especially in view the practical importance of the agent; and shall make all the remarks that I am able to include in a brief space, on the administration of chloroform in surgical operations, medicine, and midwifery.

Description of the effects of Chloroform.

I may premise, that in applying the term narcotic to chloroform and other volatile substances, I employ it in the extended sense in which it is used by writers on materia medica and toxicology, who make it include all the substances which act on the nervous system; and I apply the term narcotism to designate all the effects of a narcotic, as I am entitled to do by strict etymology, and do not confine it, as the practice has generally been, to express a state of complete insensibility. I do not object to the term anæsthetic, but I use that of narcotic as being more comprehensive, and including the other properties of these vapours as well as that of annulling common sensibility.

To facilitate the description, I divide all the effects of chloroform short of the abolition of life, into five degrees. I use the term degree in preference to stage, as, in administering chloroform, the slighter degrees of narcotism occur in the latter stages of the process, during the recovery of the patient, as well as in the beginning.

The division into degrees is made according to symptoms, which, I believe, depend entirely on the state of the nervous centres, and not according to the amount of anæsthesia, which I shall give good reason for believing depends very much on local narcotism of the nerves.

In the first degree I include any effects of chloroform that exist while the patient possesses perfect consciousness of where he is, and what is occurring around him. As the sensations caused by inhaling a small quantity of chloroform have been experienced by nearly every medical man in his own person, I need not attempt to describe them. They differ somewhat with the individual, but may be designated as a kind of inebriation, which is usually agreeable when induced for curiosity, but is often otherwise, when the patient is about to undergo an operation: in such cases, however, this stage is very transitory. Although it is the property of narcotic vapours to suspend the functions of different parts of the nervous system in succession, yet they probably influence every part of that system from the first, but in different degrees.

I have found that my vision became impaired when inhaling chloroform, whilst I should have thought it as good as ever, had it not been that the seconds pointer disappeared from the watch on the table before me; and I could only discover it again by stooping to within a few inches within it. Common sensibility becomes also impaired, so that the pain of disease, which is generally due to a morbid increase of the common sensibility, is in many cases removed, or relieved, according to its intensity. And hence it is that patients are able to inhale chloroform and ether, without assistance, for the relief of neuralgia, dysmenorrhœa, and other painful affections; the latter, which acts less rapidly, being the best adapted for this kind of domestic use—chloroform being perhaps not perfectly safe. The sufferings attendant on parturition, when not unusually severe, may generally be prevented, as stated by Dr. Murphy,* without removing the patient's consciousness; but I have met with no instance in which the more severe kind of pain caused by the knife was prevented, whilst complete consciousness existed, except in a few cases, for a short time, as the patients were recovering from the effects of the va-

* Pamphlet on chloroform in the practice of midwifery.

pour, having just before been unconscious.

In the second degree of narcotism, there is no longer correct consciousness. The mental functions are impaired, but not altogether suspended. Generally, indeed, the patient neither speaks nor moves, but it is possible for him to do both; and this degree may be considered to be analogous to delirium, and to certain states of the patient in hysteria and concussion of the brain; and it corresponds with that condition of an inebriated person, who is not dead drunk, but in the state described by the law as drunk and incapable. It is so transitory, however, that the patient emerges to consciousness in a very few minutes at the farthest, if the chloroform is discontinued. This degree, any more than the others, cannot properly be compared to natural sleep, for the patient cannot be roused at any moment to his usual state of mind. Persons sometimes remember what occurs whilst they are in this state, but generally they do not. Any dreams that the patient has, occur whilst he is in this degree, or just going into, or emerging from it, as I have satisfied myself by comparing the expressions of patients with what they have related afterwards. There is generally a considerable amount of anæsthesia connected with this degree of narcotism, and I believe that it is scarcely ever necessary to proceed beyond it in obstetric practice, not even in artificial delivery, unless for the purpose of arresting powerful uterine action, in order to facilitate turning the fœtus. For, on the one hand, obstetric operations are less painful than those in which the knife is used, and, on the other, it is not so necessary that the patient should be perfectly motionless during their performance, as when the surgeon is cutting in the immediate vicinity of vital parts.* There is sometimes a considerable amount of mental excitement in this degree, rendering the patient rather unruly; but a further dose of the vapour removes this by inducing the next degree of narcotism, and there is less difficulty from this source with chloroform than with ether, since its action is more rapid, and two or three inspirations often suffice to overcome the excitement. Very often, however, the patient is quiet, and to a certain extent tractable in this degree, and if sufficient anæsthesia can be obtained, there are certain advantages in avoiding to carry the narcotism beyond it for minor operations, especially tooth-drawing, as I shall explain when I enter on the uses and mode of applying chloroform, at the end of this sketch of its physiological effects. The patient is generally in this degree during the greater part of the time occupied in protracted operations; for, although, in most cases, it is necessary, as I have formerly stated, to induce a further amount of narcotism before the operation is commenced, it is not usually necessary to maintain it at a point beyond this.

The advent of the third degree of narcotism is marked by cessation of all voluntary motion. Usually the eyes become inclined upwards at the same time; and there is often a contracted state of the voluntary muscles, giving rise to more or less rigidity of the limbs. This contraction is greater and more frequent from chloroform than from ether, and, by affecting the muscles of the jaw, it sometimes causes a considerable obstacle to operations on the mouth. As there are no signs of ideas in this degree, I believe that there are none, and that the mental faculties are completely suspended: consequently the patient is perfectly secured against mental suffering from any thing that may be done. It does not follow, however, that an operation may always be commenced immediately the narcotism reaches this degree, for anæsthesia is not a necessary part of it; and unless the sensibility of the part to be operated on be suspended, or very much obscured, there may be involuntary movements sufficient to interfere with a delicate operation—not merely reflex movements, but also co-ordinate actions, such as animals may perform after the cerebral hemispheres are removed, the medulla oblongata being left. Under these circumstances an operation usually causes a contraction of the features expressive of pain, and sometimes moaning or cries, but

* Mr. Gream and Dr. Wm. Merriman, who have done me the honour of quoting from my essays on ether and chloroform, in their pamphlets, have applied to midwifery, what I meant to apply only to delicate and serious surgical operations, and have grounded objections on the supposed necessity of producing a deep state of narcotism.

not of an articulate kind. Whether or not these signs are to be considered proofs of pain, will depend on the definition given to the word; and if they do not interfere with the operator, or influence the recovery, they can be of no consequence, as there is no pain which has an existence for the patient. To obtain anæsthesia when it does not exist in this degree, and thus to prevent these symptoms if we desire, it is not necessary to carry the narcotism further, but only to wait at this point a few moments, giving a little chloroform occasionally to prevent recovery, and allow time for it to permeate the coats of the small vessels, and act more effectually on the nerves. The sensibility of the conjunctiva is a correct index of the general sensibility of the body; and until it is either removed or very much diminished, an operaion oft delicacy cannot be comfortably performed. Accordingly, in administering chloroform, as soon as the patient has inhaled sufficient to suspend voluntary motion,, I raise the eyelid gently, touching its free border. If no winking is occasioned the operation may begin in any case, but if it is I wait a little time, till the eyelids either become quite passive or move less briskly. The state of the eye itself is observed, by this means, at the same time. It is usually turned up, and the pupil contracted, as Mr. Sibson has stated,* in the condition which I term the third degree of narcotism. The vessels of the conjunctiva, also, are sometimes injected, but more frequently they are not.

Dr. Hughes Bennet, in his able report on the properties of chloroform,† argues that the sensibility of the nerves is not suspended under its influence, because respiration, circulation, and uterine contractions continue, which could not be the case if the sensibility of the nerves connected with these functions were destroyed. This argument would have some weight if the nerves of common sensibility did not differ from those of the organic system, or those which arise from the respiratory tract of the medulla oblongata; but, as the case stands, it has none: and there is no more difficulty in conceiving a variable degree of susceptibility and of resistance to the effects of chloroform in different sets of nerves, than in different nervous centres. A careful observation of cases shows that the amount of local insensibility by no means keeps pace with the degree of sopor or coma, but is later in coming on and going off, and varies in amount in different patients; and as we know that chloroform, like other narcotics, produces some effect on parts to which it is locally applied, the conclusion seems irresistible, that it acts on the nerves as well as on the nervous centres. This view of the subject explains some circumstances which before seemed inexplicable; such as that of the patient recovering his consciousness, and telling the bystanders that he does not feel what is being done. For, whilst the vapour is escaping from the blood by way of the lungs, there is no difficulty in understanding how the brain may recover its influence sooner than the branches and peripheral expansion of the nerves; since, in the brain, not only is the circulation more rapid, but there is little, if any, lymph external to the vessels; whilst, in the body at large, the chloroform, having transuded through the coats of the capillaries into the extra-vascular liquor sanguinis, remains there for a little time, acting on the nervous fibrillæ, before it can pass again by endosmose into the vessels. It is in young subjects, in whom, connected with the more active process of nutrition, the quantity of lymph external to the vessels is greatest, that the general insensibility most frequently remains, whilst the cerebral hemispheres are resuming their functions.

In the fourth degree of narcotism there is relaxation of the voluntary muscles, together with general insensibility. I am better acquainted with this degree as induced by ether than by chloroform, for with the latter agent the third degree appears to encroach somewhat on this; chloroform seeming to differ from ether, and approaching somewhat in its effects to benzin and bisulphuret of carbon, which, we have seen, are not attended with muscular relaxation at any stage of their effects. Accordingly, I am inclined to prefer the use of ether, to assist the reduction of dislocations and strangulated herniæ.

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* Med. Gaz., Feb. 18. I think that the turning up of the eyes is not so constant as Mr. Sibson believes, as I have been unable to observe it in some patients at any stage.

† Monthly Journal, Jan. 1848.

There is, however, often sufficient relaxation of the muscles to effect these objects even in the second degree of narcotism, especially if the effect have been kept up a little time. I was at one time inclined to believe that the functions of the spinal cord were more or less suspended in this degree, since reflex movements cannot be excited by any impressions made on the eyelids, or general surface of the body; but these reflex movements are absent in every degree of narcotism, when the common sensibility is abolished, and, therefore, the circumstance is best explained by attributing it to the narcotism of the nerves. Other functions of the spinal cord certainly remain; for the sphincters of the bladder and rectum continue contracted, and respiration goes on. The sensibility of the glottis continues, apparently unimpaired, in this degree of narcotism, but that of the pharynx is probably suspended; for, in operations on the mouth and nose, the blood sometimes finds its way into the stomach, without any visible act of swallowing. This takes place frequently, when the narcotism does not exceed the third degree. In these cases, it probably runs along the channel there is at each side of the epiglottis. The breathing is not unfrequently attended with some degree of stertor in the fourth degree; and the reason why one does not often meet with stertor in exhibiting chloroform, is, that one seldom carries the narcotism so far. There is a little stertor occasionally, even in the third degree of narcotism; and this symptom, and rigidity of the muscles, are met with altogether. There may be simple snoring in any degree of narcotism, and even in the natural sleep which often follows the state of insensibility; but it never comes on during the first minutes of the inhalation of chloroform, unless the narcotism reaches to the third or fourth degree. The iris is less sensible to light in this degree than under ordinary circumstances, and the pupil is about the usual size. I have never observed it widely dilated, or totally insensible to light.

I have not mentioned the pulse in the above outline of the action of chloroform on the human subject, as it is not indicative of the amount of narcotism. It is usually somewhat increased in force and frequency, as it is by a moderate amount of fermented liquor. This effect subsides with the effect of the vapour; but I have not remarked the pulse become slower after chloroform than it might be expected to be, in the same patient, in a state of perfect repose. 52 is the slowest pulse I have met with, and that was in a healthy man. This moderate acceleration is, I believe, the only direct effect of chloroform on the pulse. Indirectly, it may affect it in other ways. If, for instance, the breathing is interrupted by the pungency of the vapour, or from any other cause, the pulse becomes small and frequent, and when sickness is induced, it is diminished in force. If it is very frequent at the beginning of the inhalation, from mental perturbation, as is often the case, when the patient is about to undergo an operation, the frequency diminishes, as all anxiety departs with the loss of consciousness.

When animals are killed with chloroform, and not too abruptly, there is a stage between the fourth degree and the cessation of respiration in which the breathing is difficult, and sometimes slow and irregular. This I have named the fifth degree of narcotism. It is not every irregularity of breathing which is to be considered indicative of this degree,—for patients occasionally hold their breath for a short time, on account of the pungency of the vapour, and sometimes also, without any evident cause, in the second or third degree; but that need be no source of alarm. The fifth degree of narcotism, on the contrary, is the commencement of dying. I have only met with it in animals. It is sometimes accompanied with convulsive movements of the limbs—a result I never witnessed from ether.

Phenomena attending death from chloroform.

When the animal is made to breathe vapour of chloroform of such a strength that the respiration is stopped in the course of a few minutes, the heart continues to beat for a short time, and the circulation ceases only, as in asphyxia, for want of the respiration, without the heart having been brought under the influence of chloroform. The reason of this, as I explained, with respect to ether, on another occasion,* is not

* On the Inhalation of Ether, p. 81.

that the vapour is incapable of affecting the heart, but because a smaller quantity suffices to arrest the respiration, and the process of inhalation ceases, without the heart and blood-vessels being narcotised. The two following experiments illustrate and prove these points:—

Exp. 41.—A nearly full-grown rabbit was placed in a jar containing 1600 cubic inches, with 64 grs. of chloroform, being four grains to each 100 cubic inches. At first it tried to get out, afterwards it struggled involuntarily, and then sank slowly down, and lay, when four minutes had elapsed, in a flaccid condition, breathing naturally. It did not stir afterwards, except from a slight convulsive twitch of its paw once or twice. In three or four minutes more, the breathing became slower, and ten minutes after it was put in, it breathed its last. It was immediately taken out, and the stethoscope applied to the chest. The heart was heard to beat for between two and three minutes, at first nearly as rapidly as before the experiment, but more slowly and less audibly towards the end. The chest was opened a few minutes afterwards, and feeble rhythmic contractions of both auricles and ventricles were observed, not strong enough to expel the blood with which the heart was filled, but not to distension. These contractions continued unabated during the half hour the inspection continued. The lungs were perfectly healthy, and not congested. Next morning the body was rigid, and the blood in the heart and adjoining vessels coagulated. The sinuses in the cranium were filled with blood, and the vessels on the surface of the brain were somewhat injected, but not those in its substance.

Exp. 42.—Four and a half grains of chloroform were introduced into a jar containing 600 cubic inches, being three-quarters of a grain to each 100 cubic inches, and, the vapour having been equally diffused, two frogs were put in. They tried to climb up the side of the jar, as if wishing to make their escape, and one or the other occasionally ceased to breathe for a minute or two, probably from disliking the vapour, but commenced to breathe again. In about five minutes the efforts to escape ceased, and they only moved to adjust their equilibrium when the jar was disturbed. They were now breathing regularly, and continued to do so till about ten minutes after their introduction, when all voluntary power ceased, and the breathing began to be performed only at intervals. They were allowed to remain till half an hour had elapsed, during the last ten minutes of which time no respiratory movement was observed in either of them. On taking them out, and laying them on their backs, the pulsations of the heart were observed on each side of the sternum. These pulsations were the more distinct from the lungs being apparently empty. Now an experiment with chloroform on the frog does not necessarily cease with its pulmonary respiration, for it is capable of both absorbing and giving off vapour by the skin. Accordingly I continued the experiment on these frogs, placing one of them back again, in the course of two or three minutes, in the same jar, with three grains of chloroform, and the other in a jar of 400 cubic inches capacity, with five grains. They were laid on their backs, and the heart of the former one, in air containing half a grain of chloroform to each 100 cubic inches, continued to beat distinctly and regularly, 45 times in the minute, for four hours that it remained in the jar, and it was not observed to breathe during the whole time, although it was watched almost constantly. The respiration commenced again within half an hour after its removal. In about an hour it recovered its power of voluntary motion, and it was not injured by the long narcotism.

The pulsations of the heart of the other frog, in air containing a grain and a quarter of chloroform to each 100 cubic inches of air, became slower and more feeble, and in a quarter of an hour could not be observed. The frog was left in the jar a quarter of an hour longer, and removed when it had been in half an hour. The under part of the thorax was immediately opened sufficiently to expose the heart. It was moderately full of blood, but not contracting at all, and it did not evince the least irritability on being pricked, either now or after exposure to the air for some time. It is evident that the heart of this last frog became paralysed by the absorption into the blood of more vaponr, in addition to

the quantity that was sufficient to arrest the respiration. The temperature of the room during this experiment was 65°.

The effect of chloroform on the heart of the frog is further shewn by the next experiment.

Exp. 43.—A frog was placed in the jar containing 600 cubic inches, with six grains of chloroform. In twenty minutes the respiration had ceased, but the heart continued to pulsate strongly. At the end of three-quarters of an hour the pulsations were more feeble, and had diminished from 40 to 30 in the minute. An hour and five minutes from the commencement of the experiment, no movement of the heart could be observed. The frog was taken out of the vapour, and a portion of the sternum and integuments removed, so as partly to expose the heart, when it was found to be still contracting, with a very feeble undulatory motion. This motion increased in force, and, in a quarter of an hour after its removal, the heart was pulsating regularly and strongly, the ventricle apparently emptying itself perfectly. When the frog had been out twenty minutes, it was placed again in the same jar, with the same quantity of chloroform. In about ten minutes the heart's action began to fail again, and in about twenty minutes the slightest movement could no longer be perceived in it. The frog was immediately taken out, and the ventricle of the heart was pricked with a needle. In a few seconds a slight quivering was observed,—whether the result of the prick is not certain, and the action of the heart became gradually re-established as before. It was arrested a third time by exposure to the vapour; and although, in its third removal, the anterior extremities of the frog had become rigid, the heart resumed its action partially, and continued to contract feebly for three or four hours after the rigidity of death had invaded the body and limbs of the animal.* The temperature of the room was 62° during this experiment.

We learned from some of the experiments detailed in the early part of this paper, that the presence in the blood of one twenty-second part as much chloroform as it would dissolve, had the effect of arresting the respiration. From the last experiment we can determine how much it takes to stop the action of the heart. One grain of chloroform, as was stated before, produces 0·767 of a cubic inch of vapour; and at 62°— the temperature during this experiment—air, when saturated, contains 13·8 cubic inches. Therefore $0{\cdot}767 \div 13{\cdot}8$ gives 0·0555, or one-eighteenth of what the blood would dissolve as the quantity which has the effect of arresting the heart's action.

* The setting in of rigidity in the frog is accompanied by a partial change of posture, and the contraction is sometimes strong enough to move the whole body.

Phenomena attending death from Chloroform.—Post-mortem appearances.—The fatal cases of inhalation of Chloroform.

In my last communication it was shewn, that when an animal of warm blood is made to breathe the vapour of chloroform, well diluted with air, until death ensues, the heart continues to pulsate for some time after the respiration has ceased, the circulation being arrested, secondarily, by the failure of the breathing. It was also shewn, by some experiments on frogs, that chloroform has the effect of directly paralyzing the heart, when it is absorbed in a somewhat larger quantity than is required to stop the respiratory movements. It is possible, indeed, to narcotise the heart of warm-blooded animals by chloroform. When the vapour is exhibited to them in a concentrated form, the breathing and circulation appear to cease nearly together; probably, because the quantity of vapour in the lungs, at the time the breathing stops, is sufficient, when absorbed, and added to that already in the blood, to narcotise the heart. The two following experiments confirm this view.

Exp. 44.—120 grains of chloroform were put into a jar of the capacity of 600 cubic inches, which was kept accurately covered with a piece of plate-glass, and moved about to diffuse the chloroform over its sides. In a few minutes the chloroform was all converted into vapour. The temperature of the jar was 65°, the air in it was consequently nearly saturated with vapour, and contained 20 grains in each 100 cubic inches. A young rabbit was put into the jar. It was very quickly affected, and ceased to breathe in less

than a minute. It was taken out immediately the respiration ceased, and the ear was applied to its chest, but no motion of the heart was audible. The thorax was opened as quickly as possible, and when the heart was first observed it was quite motionless; but it had not been exposed to the air for a minute, before it began to contract, the auricles beginning to move first, and shortly afterwards the ventricles,—and in three or four minutes it was contracting vigorously. This recommencement of the heart's action no doubt resulted from the evaporation of the chloroform from its surface, and the consequent liberation of the nerves there situated from the influence of the vapour. Soon after the chest had been opened, a drop of chloroform was allowed to fall on the heart, and its motion instantly ceased, but gradually commenced again in the course of a few minutes, and it continued to contract feebly for some time. The lungs, which collapsed as soon as the chest was opened, were, when first observed, of a vermilion tint. This colour of the lungs is an additional proof that the circulation had not continued after the respiration ceased. There was active vermicular motion of the intestines of the rabbit when they were exposed to the air, soon after death, and a drop of chloroform being put on the ileum at once stopped the contractions at the place of contact, whilst they continued as before in the rest of the intestine. The next morning the body of the rabbit was rigid, and the blood in the heart was coagulated. The right cavities were nearly full, and the left contained a small quantity of blood. The brain was quite healthy, its vessels not being congested.

Exp. 45.—Two fluid drachms of chloroform were put into the same jar, which was placed near the fire, and moved about till the liquid was all converted into vapour, when the air within was of the temperature of 75°, saturated with chloroform, and containing about 29 grains in each 100 cubic inches. A young rabbit was put in. It first attempted to escape, then gave a little cry, and sank down on its side, and was dead three quarters of a minute after its introduction. It was immediately removed, and the ear applied to its chest, but no sound could be heard. The thorax was opened directly, and the heart observed to be perfectly motionless; but it commenced to contract after its exposure, as in the former experiment, and in a few minutes was contracting vigorously. The rabbit was placed back again in the jar, in which the vapour was still retained, except a little that escaped during the momentary removal of the cover, and the heart became quickly affected from the absorption of the vapour by its moist surface. Its contractions became more and more feeble, and at the end of four minutes had entirely ceased, and could not be excited by pricking; yet they commenced again spontaneously about ten minutes after the removal of the rabbit from the jar, but were not so strong as before. The lungs of this rabbit were of a vermilion colour when the chest was opened, and the appearances on examination of the body next day were precisely the same as in the former experiment.

It has appeared to me that the respiration and circulation cease nearly together in those instances, also, in which an animal is slowly killed by the inhalation of vapour of chloroform of moderate strength. One experiment will suffice to relate in illustration of this.

Exp. 46.—A cat, which it was requisite to destroy, was placed in a jar holding 800 cubic inches, and a fluid drachm and a half of chloroform was put in, and the jar covered. The cat made efforts to escape for the first minute; it then became insensible, and was affected with spasmodic movements for about half a minute, after which it was quite motionless, and relaxed, and the breathing ceased about two minutes after the commencement of the experiment. It was taken out, and the stethoscope applied to the chest, and the sounds of the heart's action were distinctly heard. At this moment the breathing began again, and the cat was put back into the jar, from which, however, the greater part of the vapour had escaped. It remained insensible, and the breathing after a time became very feeble, except at intervals, when it was laborious. In little more than half an hour the animal died. It was taken out as soon as the respiration ceased, but no movement of the heart could be heard. Next day the body was very rigid, the right cavities of the heart and the two cavæ were full, but not greatly

distended; the left cavities of the heart were nearly empty. All the blood was dark coloured and fluid. The lungs were collapsed and of a bright red colour. They were not congested.

Post-mortem appearances.

As might be expected from these investigations concerning the mode in which chloroform causes death, the post-mortem appearances resulting from it are neither constant nor striking. I have preserved brief notes of the examination of 14 animals killed by chloroform—3 cats, 3 rabbits, 2 guinea pigs, 4 small birds (chaffinches and larks), and 2 mice. In every instance the right cavities of the heart were more or less filled with blood, and in five cases out of the fourteen they were much distended. The left cavities of the heart contained a little blood in every instance in which their state is mentioned. The blood was fluid in one instance—that of the cat, related above. In the other instances it was coagulated—generally firmly, but in three or four cases only loosely. The lungs were quite free from congestion in ten of the animals, in the other four they were congested in patches. The head was examined in only eight instances, and in these the substance of the brain was free from congestion, and the sinuses were not particularly distended, except in two.

The fatal cases of inhalation of chloroform.

After seeing how rapidly the vapour of chloroform kills animals when it pervades to a certain extent the air they breathe, and when we recollect that it came all at once to be generally administered without any previous teaching on the subject in the schools, it ought not to surprise us, however much we are called on to deplore the circumstance, that a few cases have occurred, in different parts of the world, in which the exhibition of chloroform has been attended with fatal results; especially when we consider that the vapour has usually been so administered that its strength could not be controlled. Reflecting, indeed, on the mildness and uniformity of the action of the vapour on animals, when more diluted, as shown in some of the experiments related in the first part of these papers, we ought to feel confident that it is capable of being used with perfect safety, certainty, and precision; and this view of the subject agrees with my experience, which has extended now over a great number of cases.

I offered some remarks at the time respecting the fatal case that occurred near Newcastle.* The next case recorded is one at Cincinnati, U. S. in February last.† The remarks I made on the Newcastle case apply in a great measure to this. Although the chloroform was not administered on a handkerchief, the vapour seems to have been inhaled in too concentrated a form, as its effects were produced very rapidly. The patient inhaled from a glass globe, containing a sponge of considerable size saturated with chloroform. "Breathing at first slow; inhaled 12 or 15 times, occupying from a minute to 75 seconds," and some stumps of teeth were then immediately removed. Now, it takes three or four moderately deep inspirations, and as many expirations, to replace all the air contained at one time in the lungs. Consequently, the patient was made sufficiently insensible for the operation by the effect of about 8 to 12 inspirations, whilst the chloroform of 3 or 4 inspirations more was in the lungs, waiting to be absorbed and increase the effect. I am aware that part of this would be expired again unabsorbed as the patient continued to breathe, but that is equally true of what was inhaled at the previous inspirations; so the fact remains, that the patient must have had from one-third to one-half more chloroform than was necessary to produce what was deemed sufficient insensibility. And according to what I have observed, insensibility to pain cannot be obtained in a very rapid manner without considerable narcotism of the nervous centres—the third or fourth degree: therefore, that the patient should be in a dying state a few moments after the inhalation was discontinued, was only what might have been expected. The female friends of the patient considered that she died about two minutes after the commencement of the inhalation; and although the dentists who administered the chloroform thought that the patient lived a few minutes longer, yet, even according to their account, she was during this time in a dying condition. According to

* Med. Gaz. vol xli. p. 277.
† Ibid. vol. xlii. p. 79.

Mrs. Pearson's account, which is clear and precise, the pulse became feeble and then stopped, and the breathing ceased about the same time. This agrees with what is stated above respecting the phenomena of death when rapidly caused by chloroform, and with what was observed in the rabbits in experiments 44 and 45.

On inspecting the body, the brain was found to be in a normal state, but the vessels and sinuses of the dura mater contained a larger quantity of blood than usual, which was liquid, and mixed with some bubbles of air. The lungs were considerably, but not intensely, congested. The heart was flaccid, and all its cavaties entirely empty. It had been emptied, undoubtedly, after death. Artificial respiration was resorted to, and Mr. Sibson has remarked * that he has often known the heart to be emptied after death by artificial inflation of the lungs. Or if the head was first opened, as appears by the order in which the inspection is reported, part of the two or three ounces of fluid blood which flowed from the sinuses of the dura mater might have come from the right side of the heart, as I have seen the blood flow from the chest and out by the lateral sinuses in an inspection in which it was liquid. The blood in the case under consideration was as fluid as water in every part of the body, and the globules were thought to be altered in microscopic appearance. The causes which prevent the coagulation of the blood after death are not yet well understood, and although it is not correct, as was once supposed, that fluidity of the blood is a constant rule in certain kinds of sudden death, yet there are sufficient cases recorded where it was so, to show that it is not uncommon in the human subject when death takes place suddenly. The observations on animals, recorded above, as well as numerous others, show that it is not a characteristic property of chloroform to prevent the coagulation of the blood; and I think that the artificial respiration would assist, in more ways than one, to prevent its coagulation in this case, and one presently to be mentioned.

The next case that we have to notice occurred at Hyderabad.† The subject of it was a young woman, who required to have the distal phalanx of one of her fingers amputated. The surgeon who operated says, "I administered a drachm of chloroform in the usual way—namely, by sprinkling it on a pocket handkerchief, and causing her to inhale the vapour. She coughed a little, and then gave a few convulsive movements." When these subsided, the operation was performed, and endeavours were made to recover the patient, but in vain. Scarcely a drop of blood escaped during the operation, and the surgeon remarks, "I am inclined to think that death was almost instantaneous; for, after the convulsive movements above described, she never moved, or exhibited the smallest sign of life." There was no inspection of the body.

The case which occurred at Boulogne,* is so like the above, that we may consider the two together. The patient was a female, about 30 years of age, and took chloroform for the opening of an abscess. M. Gorré, the operator, says, "I placed over the nostrils of the patient, a handkerchief moistened with from fifteen to twenty drops at the most of chloroform. Scarcely had she taken several inspirations, when she put her hand on the handkerchief to withdraw it, and cried with a plaintive voice, "I choak!" Immediately the face became pale; [a symptom recorded also of the Newcastle case; and the one at Cincinnati] the countenance changed; the breathing embarrassed; and she foamed at the mouth. At the same instant, (and that certainly less than a minute after the beginning of the inhalation), the handkerchief moistened with chloroform was withdrawn." The operation was performed, and then efforts were made to restore the patient, but she was dead; and M. Gorré remarks that the death was without doubt complete at the moment when he made the incision.

From experiments related in former parts of these papers, the conclusion was arrived at, that to produce a degree of narcotism that would arrest the respiration, the blood must contain about one twenty-second part as much chloroform as it would dissolve; and that to narcotise the heart so as to stop its contractility, the blood must contain

* Med. Gaz. vol. xlii. p. 216.
† Ibid. p. 84.

* See Med. Gaz. vol. xlii. p. 76 and 211.

about one-eighteenth part as much as it would dissolve. By a calculation similar to that made before,* I find that half a fluid drachm is the quantity that there should be in the whole of the blood of a person of average size, to stop the respiration, and 37 minims to arrest the heart's action. In the case which occurred in India, a drachm of chloroform was placed on the handkerchief. We cannot easily suppose that more than half of this entered the patient's lungs, since the expired air carries away a portion as it passes over the handkerchief. And since, as was estimated before, only about half of what enters the lungs becomes absorbed, the remainder being expired again, there could only be about fifteen minims in the blood. This quantity, supposing the young Hindoo female was but half the average size of the adult, and this is not improbable, would only be just sufficient to cause death by arresting the respiration, without immediately stopping the heart's action, providing the chloroform were equally diffused through the whole of the blood. There is every reason, however, from the symptoms, to believe that the action of the heart was suddenly arrested; and the quantity used in the case at Boulogne would not have sufficed to cause death in any way, if it had been equally mixed with the blood. But it was not equally diffused through the circulation in either case,—there was not time for it to be so. Mr. Sibson, in treating the subject of death from chloroform,† makes some remarks in which I entirely agree. He says, "the poison penetrates to the heart from the lungs in a single pulsation, and at the beginning of the next systole the blood is sent through the coronary artery to the whole muscular tissue of the heart. The blood passing into the coronary artery is less diluted—is more strongly impregnated with chloroform—than is the blood in any other part of the system, except the lungs." By experiments 42 to 45 on frogs and rabbits, it has been shewn that chloroform will act locally on the heart; consequently, if the blood passing from the lungs to the left side of the heart should happen to contain one-eighteenth part as much vapour as it would dissolve, the patient might be suddenly killed before the nervous system in general were brought under the influence of the narcotic. A small quantity of chloroform might suffice to produce this result, if the vapour were mixed with only a limited portion of air.

The difficulty of inhaling the vapour in a concentrated form, on account of its pungency, and the further dilution of it when inhaled with the air already in the lungs, no doubt would usually prevent this kind of accident, and are in fact the reasons why it has not more often occurred. Still I believe that the patient is not safe unless the vapour is systematically mixed with so much air that no great quantity of it can be in the lungs at one time. I am of opinion that ether is incapable of causing this kind of accident; for the blood may imbibe with safety so considerable a volume of its vapour, that the quantity which the lungs can contain at once, adds but little to the effect. And I consider that a patient could only lose his life by ether, from its careless continuance for several inspirations after well-marked symptoms of danger had set in.

M. Gorré says that he poured on the handkerchief not more than fifteen to twenty drops. The drops of chloroform are very small. When dropped from an ordinary phial, nine of them are equal to about two minims, and twenty drops would be less than five minims—a very small quantity. But, as the chloroform was poured, he probably means as much as would be equal to fifteen or twenty drops of water—in fact, about as many minims; and, indeed, as it was not measured, we have no means of being certain that there was not more—say, half a fluid-drachm. However, fifteen minims might be amply sufficient to cause death in the way indicated above, even if but half of it entered the lungs; and the sudden paleness, and almost instantaneous death, clearly indicate that the circulation must have ceased suddenly.

The post-mortem appearances in the case at Boulogne were very nearly the same as in the case which occurred at Cincinnati, previously alluded to. Artificial respiration had been resorted to, and carried to the extent of permanently dilating the pulmonary vesicles.

* Med. Gaz. vol. xli. p. 894.
† Ibid. vol. xlii. p. 109.

Air was met with in the sinuses of the dura mater in the American case, and in this case a good deal of air was mixed with the blood in the veins of almost all parts of the body. There can be but little doubt that this was a result of the artificial respiration, although one cannot tell precisely in what way the result was produced. The peculiar state of the blood, which was very fluid and dark-coloured, as in the American case, must have depended rather on the suddenness of the death, and the artificial respiration, than on any immediate action of the small quantity of chloroform—a quantity much less than is usually inhaled in a surgical operation.

A patient died whilst taking chloroform during an amputation at the hip-joint, at the Hôpital Beaujon, in Paris. But the death in this instance was probably not entirely due to the chloroform; for although the patient apparently got an overdose of the vapour when it was repeated during the operation, yet, as the pulse was occasionally appreciable for three-quarters of an hour afterwards, he would most likely have recovered, had it not been for the lesion occasioned by the operation, which it seems was never finished. So the four cases previously alluded to, and which happened at Newcastle, Cincinnati, Hyderabad, and Boulogne respectively, comprise the whole of the instances in which it appears to me that death has clearly and undoubtedly resulted from the inhalation of chloroform. There was a death at Aberdeen, but not from the professional administration of the agent. There is another case, however, in which the death is generally attributed to the chloroform; and occurring, as it did, in the practice of Mr. Robinson, who has had great experience, and deservedly earned a high reputation, connected with the administration of ether and chloroform, it has made a great impression both on medical men and the public. My reasons for doubting that death was caused by chloroform in this instance are these:—Mr. Robinson's servant states, in her evidence, that the inhaler was not applied to the patient's face, but held at a little distance from it; and, with the kind of inhaler Mr. Robinson uses, it is impossible that the air the patient breathed could become strongly charged with vapour in this way; for it would pass into the mouth and nostrils by the side of the face-piece, and very little of it would pass over or through the sponge. Again, the patient was remarking that the vapour was not strong enough, just when the inhaler was removed, and the moment before he suddenly expired.* I consider that he would have made no such remark if there had been a quantity of vapour in his lungs capable of suddenly paralysing the heart. This condition of the patient is totally unlike the coughing and convulsions in the case in India, or the exclamation "I choke," in that at Boulogne. I am not inclined, however, to attribute the sudden death at that moment to a mere coincidence, as it might be occasioned by mental emotion. Fainting is not altogether peculiar to the female sex; and, supposing syncope to occur in a patient who has fatty degeneration of the substance of the heart, and an enlarged liver greatly encroaching on the space of the thorax, one can easily understand why he should not recover. In some of the reports it was stated that the patient did not appear alarmed, for he was laughing and talking the moment before he died; but I do not know why a patient should laugh in a dentist's operating chair, unless to disguise or try to banish his apprehension. He had been led by his medical attendant in the country to believe that the chloroform would be attended with danger in his case; and again, just the moment before he died, Mr. Robinson was asking him to have his teeth taken out without proceeding further with the vapour. The post-mortem appearances are quite consistent with this cause of death; and, according to this view of the subject, the disease of the internal organs assists to explain the fatal occurrence; but I do not see how it can assist in explaining it, if it be attributed to chloroform, although I am aware that it is usually thought to do so.

If the heart were so thinned that it were in danger of being ruptured by the least distension, or if some of its orifices were so contracted that it

* I do not understand why Mr. Robinson was proceeding to add more chloroform, having previously put a drachm and a half on the sponge, as applying the inhaler closer to the face would have made the vapour stronger.

could not maintain the circulation under increased exertion or excitement, I could understand how the inhalation might be attended with danger, if excitement and struggling were produced by it, as sometimes happens. And on these grounds I always looked on extensive disease of the heart as a contra-indication, to a certain extent, of inhalation, and have expressed opinions to that effect; but I cannot conceive how a moderate and gradual inhalation of chloroform should cause any person's heart, however diseased, suddenly to cease beating. There are neither facts nor analogies in support of such an occurrence. Mr. Thomas Wakley, having met with great congestion of the heart and lungs in certain of the animals that he killed with chloroform, and mistaking, in my opinion, the consequence of the mode of dying for the cause of death, had expressed an opinion that this agent would be particularly dangerous in diseases of the heart and lungs; but this case, the only one of those where death was attributed to chloroform, in which any previous disease of these organs was found, cannot be considered to support an opinion founded on these grounds; for here there was no congestion of the heart, and but very little of the lungs. I am happy to find views similar to my own, respecting chloroform in disease of the heart, entertained by one whose opinion, both on account of the attention he has paid to this subject, and his great merit as a physiologist, is entitled to so much respect as that of Mr. Sibson. He says* that "persons the subject of heart disease, when the dread of a severe operation is great, may sometimes be peculiarly benefited by the careful and short production of anæsthesia during the cutting part of an operation."

On the administration of chloroform—Objections to giving it on a handkerchief—Description of an apparatus.

The conclusion generally arrived at by those who have commented on the fatal cases of inhalation of chloroform, is one in which I do not agree. It has usually been concluded that there is danger necessarily attending the use of chloroform, and that it should therefore be confined to serious operations. Now a great part of the advantage attending the use of an anæsthetic consists in its preventing the patient's dread of the operation; but if the immunity from pain could only be obtained by incurring a danger of sudden loss of life, there would be a new source of fear. Many patients, again, have been readily induced to submit to a necessary operation, through the prospect of undergoing it without pain, who, otherwise, would have withheld their consent either altogether or till the prospect of a successful issue were much diminished. In this way, there is no doubt, many lives have been saved. But if the patient had to choose between pain and a risk, however small, of sudden death, this ready and early consent could not be expected. It is therefore necessary, for the sake of patients undergoing capital operations, to inquire whether there is any means of preventing the pain, which is free from danger, and to employ that means in preference to another. And if the skilful and careful administration of chloroform were really attended with danger, I would recommend that it should not be resorted to in any case; for we have in ether a medicine capable of affording all the benefits that can be derived from chloroform, and which never caused accidents of the kind we are considering, although it was the first used,—when the knowledge, consequently, of producing insensibility was less.*

There is, however, no reason to doubt that chloroform is, when administered with care and a sufficient knowledge of its properties, unattended with danger,—or, at all events, with a degree of danger so small that it cannot

* Loc. cit.

* I am aware that ether was thought by some to have caused death in two or three instances in which the patients did not recover from the operation, but died two or three days afterwards; and in one of these instances a coroner's jury returned a verdict to that effect; but I believe the only instance on record in which the inhalation of ether was fatal, was one that occurred in France (see Gaz. Médicale, 4 Mars, and Med. Gaz. p. 432, last vol.), and in that case the inhalation was continued without intermission for ten minutes, although alarming symptoms were present nearly all the time; and it is probable that the result was owing as much to some defect in the inhaler, which limited the supply of air, as to the effect of ether.

be estimated;—not greater, for instance, than attends the minor operations of surgery, or the taking of ordinary doses of medicine. When the vapour of chloroform is well diluted with air, it is as safe as ether; and, as it possesses some minor advantages over it,—such as being less pungent, and therefore more easily inhaled,—not leaving its odour in the breath for some time afterwards,—being more portable, on account of the smaller quantity required, and producing excitement less frequently in the early stages of its effects,—its use, by all medical men who are perfectly conversant with its effects and mode of administration, is quite allowable in every case in which there is much pain to be prevented.

But, without proper precautions, the inhalation of chloroform is undoubtedly attended with danger, on account of the rapidity of its action when not sufficiently diluted with air, and, also, on account of its effects accumulating for about twenty seconds after it is discontinued, which accumulation would be most formidable, if the air taken into the lungs just before, were highly charged with vapour. The exhibition of ether is not attended with this kind of danger, even if but little precaution is exercised, and the symptoms caused by both vapours being the same, I entirely agree in the recommendation of M. Valleix, physician to the Hôtel Dieu, that medical men who have not practised anæsthesia should first study it from the action of ether.* This advice will, perhaps, not generally be followed; but if practitioners are inclined to run any risk in administering chloroform before they are well prepared, they must recollect that they are not doing it for the sake of preventing the severe pain and shock of the operation, but only to avoid the stronger odour, more pungent flavour, and other little inconveniences of ether.

It is quite obvious, that by merely placing the chloroform on a handkerchief or sponge, and getting the patient to breathe through it, we can have no control over the quantity of vapour in the air breathed. If the handkerchief be not applied close to the face, enough vapour will, most likely, not be taken to cause insensibility; and, if applied closely, the air breathed will probably be almost saturated, and that at a rather high temperature. In three out of the four fatal cases we have considered, the chloroform was administered on a handkerchief; and in the fourth case —that in America—no attention was paid to the proportions of vapour and air: the only endeavour appeared to be to make the patient insensible as quickly as possible. The handkerchief is advocated by some practitioners, on account of its supposed simplicity; but whenever I have had occasion to give chloroform in this way, I have felt it to be a very complicated process, on account of the difficulty of getting even an approximative knowledge of what I was doing, by the best calculation I could make.

Before administering chloroform, the surgeon should have as clear and distinct an idea of its vapour as of the blade of his knife; and as this will be read by students as well as practitioners, I shall be excused for introducing a brief explanation of the nature of a vapour. In a popular sense, this term is sometimes applied to the minute globules of liquid suspended in air, which result from the condensation of a vapour that has been mixed with it, as in what is called the steam or vapour from the spout of a tea-kettle. But chloroform cannot be taken in this form; if it were attempted, spasm of the glottis would ensue. A vapour is a dry aeriform condition of a substance differing from a gas only in the circumstances of temperature and pressure under which it takes the liquid form. The vapour of chloroform has no separate existence under natural circumstances of pressure and temperature, or in any form of inhaler. No patient ever took any of it in this way, or ever will, and this is equally true of ether.* Chloroform requires a

* See MED. GAZ. p. 305, present vol.

* Many practitioners, judging from their writings, seem to have very incorrect notions concerning these vapours. For instance, M. Roux, the eminent French surgeon, in objecting to the use of the handkerchief in the Academy of Sciences, says—"In this manner the patient inspires the chloroform vapour without air. (See MED. GAZ. present vol. p. 214). Soon after the inhalation of ether was introduced, two veterinary surgeons in London endeavoured to try its effects on a horse in a pure state, and prevented the ingress of air. As they did not make the ether boil, the animal could get no vapour, except what com-

temperature of 140° Fah., under the ordinary pressure of the atmosphere, to make it boil, and enable it to exist in the state of undiluted vapour; but mixed with air, it may have the form of vapour at inferior temperatures: the quantity that may exist in the air varying with the temperature directly as the elastic force of the vapour. The chloroform, in fact, that a patient breathes, is dissolved in the air, just as water is always dissolved in it, even in the driest weather, and the patient breathes his air with two vapours instead of one—the new vapour being, to be sure, in much the largest quantity. As a proof that these physical considerations are worthy our notice, I may state, that if chloroform had boiled at 180° instead of 140°, its solubility and other properties remaining the same, the four fatal cases we had occasion to discuss would not have occurred.

The following table shews the result of experiments I made to determine the quantity of vapour of chloroform that 100 cubic inches of air will take up at various temperatures:—

Temperature.	Cubic inches.
50°	9
55	11
60	14
65	19
70	24
75	29
80	36
85	44
90	55

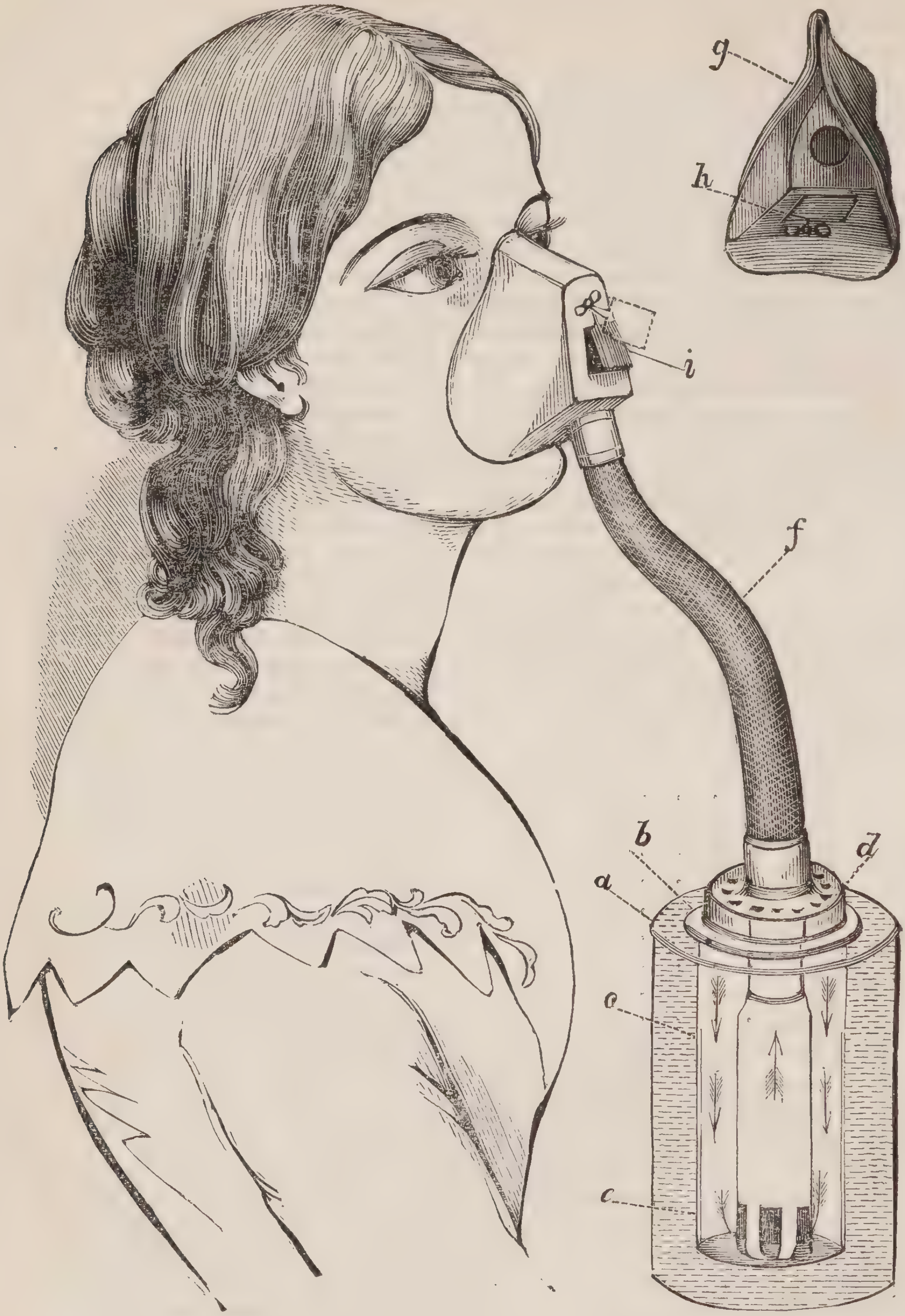
The most perfect way of giving a vapour to animals is that adopted in the experiments I have related, the breathing not being interfered with, and the strength of the vapour being accurately known. This method is not applicable to patients, but our endeavour should be to approach to it as nearly as we conveniently can. The apparatus I employ is delineated in the subjoined engraving.* (See next page).

bined with the little air that might get in through the leakage of the inhaler. The horse in fact was burked. The efforts at respiration were prodigious,—it shortly died,—and the heart and diaphragm were found to be ruptured. (See Lancet, April 10, 1847). This experiment has been recently quoted in a pamphlet opposed to chloroform in midwifery, as a proof of the injurious effects of ether.

* It is made according to my directions, by Mr. Matthews, 10, Portugal Street, Lincoln's Inn Fields.

a. Outer case containing water bath, screwed on—*b.* Cylindrical vessel into which the chloroform is put; it is lined with a coil or two of bibulous paper up to the point *c d.* A cylindrical frame which screws into *b*—it has apertures at the top for the admission of air, and its lower two-thirds are covered with a coil or two of bibulous paper, which touches the bottom of the vessel *b*, except where the notches *e* are cut in it. *f.* Elastic tube. *g.* Expiratory valve of face piece; the dotted lines indicate the position of this valve when turned aside for the admission of air not charged with vapour. *h.* Inside view of face-piece, pinched together at the top to adapt it to a smaller face. *i.* Inspiratory valve.

When the patient inspires, the air enters by the numerous and large apertures in the top of the inhaler, passes between the two cylinders of bibulous paper, wet with chloroform, through the notches in the bottom of the inner one, then up the centre of the apparatus, still in contact with the paper, and through the short tube, which is three-quarters of an inch wide in the inside. The air thus gets charged with vapour, whilst it meets with no obstruction whatever till it arrives at the inspiratory valve of vulcanized India-rubber, which weighs but a few grains, and rises at the beginning of the slightest possible inspiratory movement. The cylinder of thin brass in which the chloroform is placed is inclosed in a larger one containing water, which, by supplying the caloric that is removed in the vaporization of the medicine, prevents the temperature from being lowered. It also prevents it from being raised by the warmth of the hand, and thus keeps the process steady. If the temperature of the water be 60°, each 100 cubic inches of air passing through the apparatus might, according to the table above, take up 14 cubic inches, and become expanded to 114 cubic inches, when it would contain a little more than twelve per cent. by measure. This is supposing it became quite saturated, which, however, it does not, and ten per cent. of vapour, or eight minims of chloroform, is probably as much as the air contains. It is not desirable, however, to give it to the patient even of this strength, and the



expiratory valve of the face-piece * is made to move to one side, so as to leave uncovered more or less of the aperture over which it is placed, and admit pure air to mix with and dilute that which has passed through the inhaler. By means of this valve, the vapour may be diluted to any extent, whilst, at the same time, one may have a knowledge of the strength of the

* It is the same face-piece I used in giving ether for three or four months before Dr. Simpson introduced the use of chloroform. By the removal of the peculiar expiratory valve, which is its most important part, and the introduction of a sponge, it has been made to constitute a chloroform inhaler by more than one practitioner. These inhalers are, undoubtedly, better than the sponge or handkerchief; but, besides the want of affording due command over the strength of the vapour, I consider that they are open to objection from the chloroform being so near to the mouth, that some of it might be inhaled, by a forcible inspiration, in the form of minute drops, when it would cause temporary spasm of the glottis.

vapour the patient is breathing; not exact, to be sure, but practically of great value. The valves in this face-piece act properly, and close of themselves, in every position in which a patient can be placed, except on his face, and even in this posture they will act if the head be turned on one side.

The position of the patient and inhaler have nothing to do with the specific gravity of the vapour, as some have supposed. If what the patient breathes were as heavy as the pure vapour, it would impose no appreciable labour on the muscles of respiration to raise it to the mouth; and although the vapour of chloroform is four times as heavy as atmospheric air, it does not increase the specific gravity of the air the patient inhales by more than one-fourth; and, indeed, air charged with vapour of chloroform is not so heavy as when charged with vapour of ether at the same temperature. The most convenient position of the patient taking chloroform is lying on the back or side, with the head and shoulders a little raised, as he is then duly supported in the state of insensibility, and can be more easily controlled if he shall struggle whilst becoming insensible. But there is no objection to the sitting posture, when that is most convenient to the operator.

In the next paper, I shall enter on the details necessary to be observed in giving chloroform in different kinds of surgical operations.